JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE

PROMOTION OF THE MECHANIC ARTS.

VOL. CII. AUGUST, 1876. No. 2.

EDITORIAL.

NOTICE.—The publication of the JOURNAL is made under the direction of the Editor and the Committee of Publication, who endeavor to exercise such supervision of its articles, as will prevent the inculcation of errors or the advocacy of special interests, and will produce an instructive and entertaining periodical; but it must be recognized that the Franklin Institute is not responsible, as a body, for the statements and opinions advanced in its pages.

Practical Information for Practical Men.—The general idea that practical information useful to a practical man can be made interesting or instructive to the ordinary reader, is an altogether erroneous one. Admitting that the experienced workman in any position in the scale of productive labor desires information relating to the advances in theory or practice in his particular field of labor or description of product, it must be asserted that as regards both theory and practice he is in his way fully informed already—quite as thoroughly as any general instructor likely to offer to inform him—and he will not tolerate the kind of incomplete description and imperfect reasoning which passes for knowledge to the uninitiated. He demands that his informant shall start from his standpoint and make available his basis of facts and experience in the attempt to communicate that which was hitherto unknown or unappreciated, but it is now essayed to make known and comprehensible.

In one sense, elementary science can be called practical information, and to the school boy or the apprentice it unquestionably is so. A knowledge in elementary science is essential to the practical man or the mechanic; but to the latter the mere reiteration of fundamental principles, however happily clothed in new words, and embellished with striking examples, ceases to be practical information. There are numerous admirable text books, in which will be found collated information in all branches of science—books ranging from the elementary to the most profound treatises on their several subjects—which place before the studious and diligent reader the means for acquiring knowledge in any degree. For those whose ability, inclination or opportunity does not admit the close study which entire comprehension involves, there have been provided hand books of the several trades or callings in industry, and special works on mechanical construction, wherein it is only needful to search to find the facts and figures of usual reference and application. In fact the record of theory and practice in technical pursuits, and especially of mechanical construction, in books, journals, magazines and newspapers, not to omit the same record in patents and circulars, is voluminous and uninteresting in the extreme, except only to those whose daily labor or whose special field of research demands their perusal. On the whole a dictionary is an entertaining book to read through, compared to an encyclopedia of machinery; and a government document of expenditures, of an ancient date, is enlivening, compared to a mechanics' magazine of the same antiquity.

The text books or the hand books may not be all that could be wished by the critical, either in method, completeness or thoroughness, yet any practical man in any field of industry, who studies them, comes to appreciate their deficiencies as well as their merits. His acquired "book knowledge" will lead him to doubt any assertion, as well of fact as of conclusion, when his understanding has not brought him to accept it, without much regard to the authority from which the assertion was derived. Thought, consideration, study, are the price to be paid for information by the best educated and the most practical. It is not possible for the idle, the inconsiderate, or the unthinking to obtain knowledge or an available substitute for it, in nostrums or receipts, from the brief reading of entertaining notices in the newspapers, the popular articles on surprising science in the magazines, or the brilliant experimental demonstrations of the lecture room.

The general public does not understand these propositions and curiously enough, the practical man, when the information set forth in the newspaper, magazine or lecture room is beyond his individual knowledge is as likely to be pleased by scientific fireworks as the rest of the community, while he would decidedly condemn the superficial, misleading statements if they came within the scope of his own information or were applied to his own methods.

There has been a time when elementary information on physics, chemistry or mechanism was "information to practical men," and that time has been a comparatively recent one. Less than fifty years ago the "Society for the diffusion of useful knowledge" was issuing a set of text books in the form of tracts on these subjects. Nowhere else in the English language did the information exist in a form available for self-acquisition; and the completeness, clearness and simplicity of the treatises published by the society have not since been excelled—or in the first regard, completeness—not yet been equaled. These treatises supplied a want in their day, but are somewhat antiquated at this time, and they have been superseded by others on the same subjects which have maintained generally the record of the advance of science, its growth and accretion. There has been a great change in the habits of the English people, and one more marked in the same direction in those of the American half of the family, in the way of careful and studious reading. Fifty years since, the well read Englishman (in English literature) would quote pages from the *Spectator*, or from Locke; from Burke or from Gibbon; from the "Lay" or "Childe Harold,' with little apparent task on his memory, and he read to learn to quote, or to use any book, page and line in this manner. The treatises of the society were written and printed to satisfy such readers, and many such were found. A similar set of related and connected treatises, written up to the most advanced scientific knowledge of the day, would be an excellent addition to our literature, but it is more than questionable if they would find readers and students as of old.

Popular lectures, entertaining descriptions, both oral and written, upon the teachings of elementary, as well as upon the results and phenomena of profound science; presentations and illustrations of facts in chemistry, physics, mechanism or construction, will constantly be repeated; they may gratify the popular taste, but they can never again be practical information for practical men. The standard of

the present and the future is a higher one. He who is a practical man now (or hereafter) must have acquired in the course of his practice an experience in some peculiar direction of knowledge, enough to have compelled him to have learned its "science," regularly and methodically, to have investigated by his reasoning faculties and founded himself upon principles, and not on half comprehended rules.

This process of self-education is an easy one to him who would learn. Possibly there are certain preliminary steps, which it is hard to take if there is a deficiency in primary education. Thus the ability to read and write, and to use the rules of arithmetic and simple algebra are indispensable to the beginner in higher studies, and this ability is difficult for the untaught mind as a self-acquisition. Allowing that there are practical men who do not possess this ability, or are deficient in their arithmetic and algebra (as is sometimes pleaded), so that they cannot study the text books, or use the hand books; and that for them, practical information should be prepared. Such an allowance implies:—Only, that he who is incapable of understanding the text books or hand books, so far as they refer to his calling, is equally incapable of judging as to the truth or error of the assertion of the writer or lecturer, upon whom he is supposed to rely. To such a one, unless his informant were infallible, it were better that he should not be *informed* at all. There is no royal road to learning; its acquisition without study is like the acquisition of wealth without labor. It is as necessary for the mechanic to study out his problem when it comes to him to be studied, as it is for him to finish his task by his handicraft.

There are those who teach a different doctrine. Some who have known better, have courted notoriety, popularity, and profitable reward, by advertising the easy method of learning without effort. The art of popular scientific lecturing is understood to consist in demonstrations, which every one can comprehend, accompanied with assertions supported by *satisfactory* experiments. It seems to have become the peculiar assumption of the half informed man, that he shall use his eloquence, if not his ignorance, in instructing those who are not informed at all. But the really practical man appreciates these things. How many times he will have read or listened to an account of an apparatus, process, or product, with which his knowledge is complete, and known the whole to be fraudulent or erroneous?

The course of lectures unquestionably occupy a place in the system of education—enlivening, illustrating and elucidating the studies from the book. Even the desultory lecture serves its end in giving general information and intellectual entertainment. It does its part, and a large one it is, in forming an intelligent, if not a thoroughly informed community. A great end is subserved if some persons are educated to appreciate knowledge. The popular magazine, or the popular science of the newspapers, in the same way answers the same purpose. But all this knowledge is ephemereal and of little value to the practical man.

The progress and advance of the arts and sciences are positive facts. Hand in hand, the one or the other, art or science, leads. With the multitude of thinking artisans, art most frequently goes before where science follows, but in the end, under the direction of other artisans, or in other fields, science gives the permanent guidance for art, and the "ample page, rich with the spoils of time," unfolds to each successive generation what their ancestors so laboriously acquired. Thus enlightened, it is the progress and advance of the arts and sciences, not the arts and sciences themselves, that the practical man needs information about.

The action of the managers of the Franklin Institute, from the organization of the Institute to the present time, has been consistent with the views now expressed. For the purposes of education of those who needed it, they established courses of lectures on scientific subjects, which have been maintained to the present time. In the origin of the Institute it was probably supposed that the instructive element would predominate more largely in its proceedings than has actually occurred. School education on the same topics has become so universal that the later generations do not need, nor do they take much interest in such lectures as commanded crowded and attentive audiences years ago. Still a measure of interest is kept up in the same class of teaching, which each generation must repeat and acquire for itself, and the popular lecture at the Franklin Institute is yet somewhat more than an entertaining pastime.

But in the labors of the Institute the founders and subsequent managers pursued, as practical men, another direction. Take two striking instances in the early history of the Institute—the inquiry into the law of the expansive force of steam, and that into the cause of boiler explosions. Knowledge on these subjects, above all others,

is necessary information for practical men, but then the investigation was tedious, the discussion was recondite, and the concluding results were unintelligible, almost incomprehensible, to any others than practical men in an extremely limited kind of practice. All the early proceedings of the Institute, as published in the JOURNAL, exhibit the same direction; and for the JOURNAL itself, the standard adopted was, that it should be made the record of the advance of science and the arts, rather than merely educational and popular. There is found on its pages, therefore, the briefest of allusion to the classes of study, courses of lectures, and of current events; but instead of these, are given the most thorough and elaborate reasoning and formula that might be required to support and demonstrate each or any scientific development. The reputation of the Franklin Institute as established by its JOURNAL in the earlier years, in marking the successive strides in arts and science for fifty years, is deservedly one to be proud of.

This reputation the present editor has endeavored to maintain, but he is fully aware that it is at a cost of popularity. If there are now, at this present time, many more writers on scientific subjects, and much more novelty evolved, than when this JOURNAL came into existence, there are also yet more "scientific" publications, so that the "offerings" to the JOURNAL are not so numerous as of old. Much that is now written appears in newspapers, and although grains of wheat exist, yet the chaff predominates in the loose literature from which the wheat is to be selected; if such selection be made at all, by more than editor's skill. It follows that the task of securing good, practical articles is not an easy one.

But the point in issue is the one relating to the popularity of practical information, and, at the risk of some self laudation, it can be well exemplified by the past year's articles in the JOURNAL. Take the article on quadruplex telegraphy, which is a description in the simplest language, by a practical man, giving to any other practical telegrapher a clear and comprehensive account of the novel procedure. That upon Determination of Roof Strains, which is a practical exhibition of a method which all roof constructors should learn, for the ready, simple and accurate understanding of their work: That upon Chimneys for Steam Boilers, which gives a table covering all usual chimneys for stationary engines, and formulæ which will apply to all others: That relating to the theory of lenses, which supple-

ments previous theories by those which have come to be understood as applied to the lens of the photographer or the microscopist of to-day: That on trials of expansive and non-expansive engines: Other papers which have appeared during the past twelve months might be quoted, all of which, without exception, have the least possible interest, *except* to practical men; but they are of the highest importance to them. It might be claimed that, practically, it would have answered the same purpose if all the reasoning, computation and formula which formed the bulk of these articles had been omitted. And this is partly true, if it is to be assumed that the editor of the JOURNAL was an infallible judge of each article, or the author above scrutiny, and no further dictum than mere placing of results before readers was necessary. Such unqualified confidence is not to be supposed, and the sole alternative is to present for consideration all the data and processes of treatment by which the conclusions were attained, and challenge examination and criticism.

Finally, it may be asserted that there is an incompatibility now and for all time, between practical and popular information.

The Pennsylvania Museum and School of Industrial Art.—*Report of J. B. Knight, Trustee, in behalf of the Franklin Institute June* 21, 1876.—This association was first organized, as you are probably aware, about a year ago, "to establish for the state of Pennsylvania, in the city of Philadelphia, a museum of art in all its branches and technical applications, and with a special view to the development of the art industries of the state."

The plan of organization provided that several institutions and corporate bodies of the city and state should be represented in its board of trustees. Among these is the Franklin Institute, and in January last you did me the honor to elect me to represent the Institute in said board.

The charter obtained under the statutes of the commonwealth, was approved by the court on Feb. 26th last, and the permanent organization of the association was completed immediately afterward by the election of officers and adoption of by-laws.

One of the first things done by the preliminary organization was to secure the permanent use of Memorial Hall after the close of the exhibition, and this is assured by the authorities having the control of the building.

In the meantime efforts were made to obtain subscriptions to its fund, with considerable success, and this has been pushed more vigorously since, until there has been secured about $40,000. With this fund the committee on selection have made considerable contracts of purchase, and have secured many valuable and desirable articles.

The selections for purchase were made with the view of cultivating a correct taste in the art of designing and decorating, and to show as far as possible the styles employed in different ages and countries, avoiding repetition as far as possible, and in no case were articles selected because they were merely curious.

In addition to the articles purchased, several valuable ones have been presented by the makers, and several of the commissions in charge of government exhibits have indicated that we may expect some very desirable gifts from their collections.

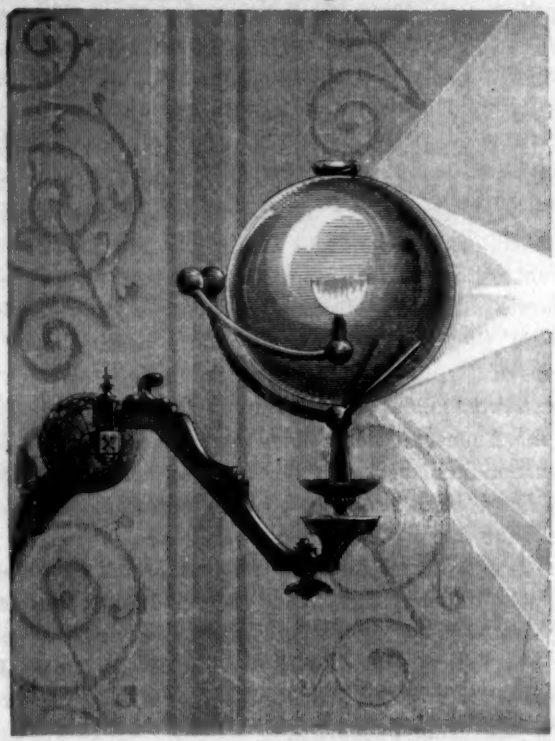
Your representative has been made the chairman of the committee on the *mechanic arts*, and has made such efforts as are within his power to secure drawings and models of such works in civil and mechanical engineering as will illustrate the most advanced state of these arts, as well as something of their history.

One has but to study the influence such institutions have on the industries of a people, even in the most cultivated nations, to realize the great importance this one must be to us; and as we find foreign as well as American institutions competing with us in the purchase of articles, it is believed that Pennsylvania is not a day too soon in its efforts to establish this museum on a firm basis.

In the accomplishment of the object in view money is needed, in raising which all can assist by becoming contributing members, and paying $10 per year, or a life member by paying $100 at one time, or by subscribing larger amounts, each additional $100 of which entitles such member to an additional vote at the annual election. Several subscriptions of $5000 have been received. No better investment can be made by those who are able, to take their dividends, in increased comforts, improved tastes, and increased prosperity of their country.

The Franklin Institute as a body and its individual members, have ever been foremost in promoting and fostering the educational interest of our city and state, and it is to be confidently hoped that similar assistance will be extended to this important branch of technical training, and for the establishment of which this seems to be the proper time.

Report of the Committee of Science and the Arts on the Dioptric Light of Gen. M. C. Meigs.



HALL OF THE FRANKLIN INSTITUTE,
Philadelphia, September, 1875.

The Sub-Committee of the Committee of Science and the Arts, constituted by the Franklin Institute of the State of Pennsylvania, to whom was referred for examination the improved "Dioptric or Water-light," invented and patented by Gen. M. C. Meigs, U. S. Army, report that they have examined the same, and consider the arrangement of the bracket tubing with a swing joint adapted to the curve of the glass water globe, and through which the gas passes to the burner, as very meritorious; thereby securing such movement of the burner around the globe, as to enable the concentrated rays of light to be thrown upon any desired spot, or limited area of space.

The use of glass globes, or bowls filled with water as condensers of light, has long been practiced by mechanics, artisans, and others, but

generally in very crude portable forms. The patented combination of its use in this instance is so very neatly and permanently adapted to any of the present styles of illumination, that its introduction to a great variety of purposes, would seem to be secured thereby :—

The glass globe being an enclosed one, with the exception of a small filling hole at the top, renders the fluid not subject to any agitation, or the admission of any dust or other impurities, which would materially affect the transmission of the refracted rays of light passing through the water; as also retaining its transparency, preventing much evaporation, and keeping it serviceable for months without replenishing. In these respects it is greatly superior to the "water bowl," which rapidly accumulates dust, and is subject to disturbances of the fluid, by currents of air passing over it. For a comparison of its light, *with* and without the glass globe, a very careful test was made on a "Bunsen Photometer" of 100″ scale made by the American meter company. The test was made with the fish-tail burner furnished with the bracket, consuming *five cubic feet of gas per hour*, at a pressure of *nine-tenths of an inch* column of water—and the same *elements* existing during the whole time of the test. The results are as follows, and expressed in standard candles, consuming one hundred and twenty grains of sperm per hour. With the globe attached the light concentrated upon the screen of the photometer gave a result of 90·75 *candles*, in the centre of a field of illumination of 3 or 4 ft. diameter—*without the globe attached*, the light from the same burner, gave a result of 16 candles upon the screen of photometer. It must be remarked in explanation that the light of the area of said illuminated field, is restricted to the focal dimensions, due to the diameter of the globe; and was not diffused throughout the apartment, as was the case during the tests without the globe. It is therefore to be distinctly understood, that, for all the purposes to which this invention may be applied, such as reading, writing, drawing, engraving, etc., etc., the strength of light is materially increased only within the concentrated rays of the globe condenser. As a basis of economy, taking the quantity of gas consumed as 5 cubic feet per hour, and equal to 16 candles, giving a reasonably satisfactory light to whole apartment, *without the globe*—and *with the globe* we have the same quantity of gas consumed per hour and a light concentrated upon an area of 2 sq. ft. of 90·75 candles, or 28·35 cubic ft. of gas per hour.

MEMORANDA OF TEST.

	With globe.	Without globe.
Gas consumed per hour. . . .	5. c.ft.	5. c.ft.
Pressure of gas	·9 inches.	·9 inches.
Distance gas from screen . . .	90·5 "	80· "
" candle " " . . .	9·5 "	20· "

For the intensity of light, the photometric formula is: As the squares of the respective distances—

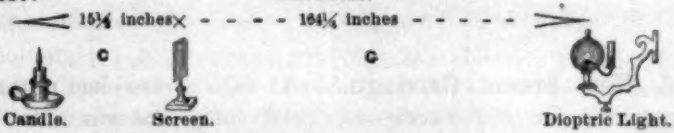
With globe. Without globe.

$$\frac{2)90\cdot5}{9\cdot5} = \frac{8190\cdot25}{90\cdot25} = 90\cdot75 \qquad \frac{2)80}{20} = \frac{6400}{400} = 16 \text{ candles.}$$

Respectfully submitted:

(Signed) HENRY CARTWRIGHT, *Chairman.*
SAMUEL SARTAIN.
JOSEPH ZENTMAYER.
Sub-Committee.

Dioptric Light.—The following abstract from a communication from General Meigs on the subject of his light, taken in connection with the report of the Committee of Science and Art, will explain itself. "The results obtained by the committee (although highly favorable in comparison to the ordinary gas light) are so much below those which were obtained at the Gas Inspector's office in this city (Washington, D. C.), when I was present, that I sent a note of the test:—



Test of the Meigs dioptric light, with gas jet, burning five cubic feet of gas per hour, of 16 candles power, in comparison with a standard sperm candle at the U. S. Gas Inspector's office in Washington, D. C.

The screen of translucent glass being placed as on the cut, so as to exhibit an equal illumination on each side, the distance $C = 15\frac{1}{2}$, and $G = 164\frac{1}{2}$:—The candle burnt at the rate of 132 grains per hour in place of 120 grains per hour, which is the *standard* quantity for comparison:—The Argand burner consumed at the rate of 4·75 cubic feet per hour, in place of 5 cubic feet per hour, which is the standard quantity:—The gas was tested to be 16 candle gas by another observation.

COMPUTATION.

$$\frac{G^2}{C^2} = \frac{27060{\cdot}25}{240{\cdot}25} = 112{\cdot}60 \times \frac{132}{120} \times \frac{5}{4{\cdot}75} = 130 \text{ candles.}$$

That is, the value of the beam of light equals that of 130 standard sperm candles, or 8·12 standard Argand burners (each of 16 candle power).

I have since, with rude apparatus fitted up by myself, compared the results of a five foot Argand burner to the effect of a six foot fish tail burner which I prefer, and now use exclusively. (The committee had a five foot burner, and I suspect it was not adjusted to the best focus.)

A six inch globe has a focal length for parallel rays of three inches. But for illuminating we do not need a parallel beam, but a somewhat divergent one, so as to give an illuminated field of considerable extent, without a sharp image for the flame, and between astigmation and dispersion of the rays to produce a diffused light, devoid of flicker or unequality. I find that the proper position for the jet is with its flame perpendicular to the axis of the divergent beam and tangent to a sphere $4\frac{1}{4}$ to $4\frac{3}{8}$ inches radius, *i. e.*, its centre to be $1\frac{1}{4}$ to $1\frac{3}{8}$ inches distant from the surface of the globe. If further off, or nearer, the field is not sufficiently illuminated.

The six foot burner, while it gives the more satisfactory light, is *not* the most economical, by some small difference in the resulting effect, but the light is sufficient for reading a newspaper at a distance of 20 feet with ease, and at 10 to 15 feet it thoroughly illuminates the paper on a draughtsman's drawing board. Of course, most of the obnoxious difficulty from heat, upon the person using the light, is avoided.

A New Steam Carriage.*—A vehicle has lately made its appearance in the streets of Paris fully deserving the name of "steam carriage," for it moves freely and easily through streets and squares, turns the sharpest corners, stops, turns aside, or goes in the same pace with a row of cabs and omnibuses, along bridges and thoroughfares. This carriage is constructed by M. Bollée, civil engineer, of Mans, for his own use. It weighs, with water and store of coals, but without passengers, nearly 4 tons; with twelve passengers, about $4\frac{3}{4}$ tons, which weight is distributed on the four wheels of the carriage as follows:—The two driving-wheels, of a diameter of 3·87 ft. and a thickness of 4·7 in., which are behind, have to sustain a weight of nearly $3\frac{1}{2}$ tons; the front (steering) wheels, of a diameter of 3·12 ft., the remaining $1\frac{1}{4}$ tons. The latter are com-

* From the *Builder*, London, April, 1876.

pletely independent of each other, and may be altered at will by the driver, who here supplies the place of the coachman, for guiding the carriage. The driving-wheels, although they are on a common axle, are not keyed to it, and receive their movement each from a pair of cylinders fixed between the wheels, and driving in the first place an intermediate axle, from which the movement is transmitted by means of a chain to the respective wheel.

The cylinders have a diameter of 4 in., and a stroke of 6·3 in. They are provided with Stephenson's link-motion, and the supply of steam is regulated in such a manner that in turning a curve it may be shut off entirely from the pair of cylinders on the inner side of the curve.

The boiler, finally, which is at the end of the carriage, is constructed on Field's system, vertical, with 194 tubes of 1·06 in. outer diameter, has a diameter of 2 ft. 7½ in., and a height of 3 ft. 3 in. All the parts are of the best materials, and made as light as possible, which accounts for the slight weight of the carriage. The consumption of water (according to the *Comptes Rendus*, p. 762) is 132 gallons per hour, if fully loaded, and at a speed of 9·3 miles per hour. At that rate, the consumption of coal is 176 lbs. per hour, which compares favorably with that of other street locomotives.

Note upon the Direction of Currents in a Crowd in Open Air.—At the gathering of people on the occasion of the opening of the Centennial Exhibition on the 10th of May, 1876, a striking example and illustration was observed of the fact that a crowd lives only by aid of the ascending current from the bodies of the persons composing it. The observer was sitting on the platform in front of Memorial Hall, and all the space between this platform and the Main Building, a space of probably 150 feet in width by 500 feet in length (of dense crowd), was occupied by about 40,000 persons, standing as closely as comfort would allow. The air was quite warm, about 75° Fah., and a light breeze was blowing from the west. There were many smokers in the crowd, and it was noticeable that the course of tobacco smoke, which showed white against the brown front of the Main Exhibition building, indicated the course of the current at different points. A breath of smoke on the outskirts of the crowd was dispersed irregularly. A puff of white smoke anywhere towards the middle of the crowd rose with great apparent rapidity until it was lost to sight by ascending above the line of roof of the building; the background of white clouds, with which the blue sky was then broken, not allowing it to be distinguished higher up. The swiftness with which the smoke rose showed that the ascending current in the centre of so thickly thronged and so large a space, was rapid. In fact it showed a set of currents like those at a fire—on the outskirts tending towards the centre, in the centre upwards. M. C. M.

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Civil and Mechanical Engineering.

ON THE CIRCULATION OF WATER IN STEAM BOILERS.

ADDRESS BEFORE THE

AMERICAN RAILWAY MASTER MECHANICS' ASSOCIATION,

at their Meeting in Philadelphia, June, 1876.

By Robert Briggs, C. E.

Mr. President and Gentlemen:—I am much gratified by the honor conferred upon me in being requested to address you upon the subject of the phenomena attending the ebullition of water, and with the risk that I may be reciting facts well known to all, and certainty that what I shall say will be merely elementary, I venture to quote a portion of a lecture delivered by me before the Franklin Institute, trusting that a new view of old facts may not be out of place.

The three forms of matter—solid, liquid and gaseous—are incident to some definite quantity of heat which accompanies each form, which is known as the latent heat, and varies in amount for the different substances. For water, which is the substance under consideration at this time, the latent heat added to and absorbed in the change of form from ice at 32° to water at the same temperature, is 142°·65 (Person), and in the change of form from water to steam of 32° is 1,092° (Regnault). But the sensible temperature of a liquid at which it will vaporize is found to vary with the pressure (or tension) of the vapor above it, and the tension of steam at 32° is only 0·085 lbs. per square inch, while the pressure of the atmosphere is 14·7 lbs. per square inch. Ebullition or free boiling of water does not take place under atmospheric pressure until the water is heated up to 212°, at which point the tension of steam is equal to the usual atmospheric pressure of 14·7 lbs. per square inch, and the latent heat of change of form from water at 212° to steam at the same temperature, is 966° (Regnault).

The other properties of water, as regards heat, with which we have to do in considering the circulation in a boiler, are its expan-

sion and its rate of conductivity. Water expands (on being heated) at anomalous rates: about 0·8 per cent. from 40° to 100°, about 3·9 per cent. from 40° to 200°, about 8·7 per cent. from 40° to 300° and about 11·5 per cent. from 40° to 350°. The conductivity of water is exceedingly slow (as it is in all liquids when not in motion), so slow that it can be assumed to be absolutely non-conducting in the present inquiry. As a consequence of this non-conductivity of water, it can only be heated by the application of heat below, and by transfer and diffusion of the state of heat by means of the motion of the particles of the fluid mass; and uniformity of temperature is attained in such a mass only by continual circulation.

The usual and accepted method of heating water, therefore, is by placing it in a vessel, to the under side of which, heat is applied, which heat is transferred through the material of the vessel and imparted to the water. The film of water in contact with the inner surface of the vessel, at the place where its outer surface is exposed to the fire, becomes heated and expands and mixes with the water immediately near it, until a stratum of water is formed which is lighter than the mass of water above it and tends to float, and its flow being supplied instantly by heavier water, a circulation is commenced. After the establishment of a circulation of slow velocity, acceleration goes on, until at some rate of movement, the friction of the currents of water against the sides of the vessel or against themselves (for eddies, whirlpools and cross-currents will form in a vessel under such circumstances) offers a resistance to greater velocity, exactly equal in amount to the disturbing force of the expanded water in trying to rise. The slow run of first movement with gradual increase of velocity and circulation, arises from the fact that particles of water are, in common with those of other bodies, either solid, liquid or gaseous, subject to the laws of the application of force; whereby they do not commence to move until some resistance is overcome, nor do they cease to move until the acquired momentum is compensated. So long as the heat imparted to the water is below the boiling point, a circulation of hot water can be urged with perfect quietness in properly formed vessels, and in tubes, until an equilibrium of temperature of the water in the vessel, or tube, is established; and when the heat of the water is abstracted in the course of circulation, a high velocity of current can be attained, and great quantities of heat can be transferred without disturbance of flow.

But as the boiling point approaches, another train of conditions is brought to bear, which may be better considered by referring to the accompanying figure.

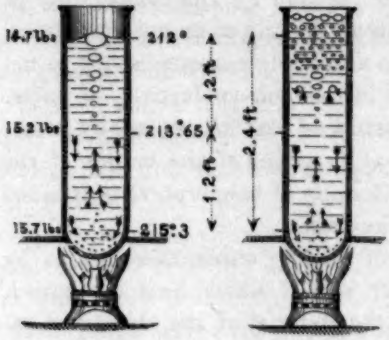

Fig. 1. Fig. 2.

Fig. 1 represents a vessel containing water exposed to the action of a fire upon or under the bottom of a vessel. It is supposed that the depth of water in the vessel is 2·4 feet, when it would follow, as the weight of a cubic foot of water at 212° is very nearly 60 lbs., that the pressure of the column of water at the bottom of the vessel is very nearly one pound per square inch. The relations of pressures and of temperatures of ebullition, in this column of water are: at the surface there will be the pressure of the atmosphere = 14·7 lbs., with its corresponding temperature of ebullition = 212°; at the depth of 1·2 feet the pressure will be 15·2 lbs., and the temperature of ebullition = 213°·65; and at the bottom, at the depth of 2·4 feet, the pressure will be 15·7 lbs., and the temperature of ebullition 215°·3.

The effect of the application of fire to the bottom of this vessel having first been admitted to raise the temperature of the entire mass of water to 212°, and having expelled most of the air which was absorbed in the water at its normal temperature before heating, will next be extended to the formation of steam as the means of dispersing the constant addition of heat; and somewhere in the height of the column, a point will be reached where the rate of circulation will permit the return water from the top surface, which will inevitably have the temperature of 212°, to reach the bottom where it will be heated, let us say, to 213°·65 by the fire.

The specific heat of water compared to that of iron is very great (about nine times as great), and a film of water of the same thickness as a sheet of iron, with which it may be in contact, has a little the greater capacity for heat; but the rapidity of convection of heat in water is far greater than that of the conduction in iron, so the general temperature of the water in contact with the iron is maintained with the smallest excess of temperature of the iron.

The extreme tenuity of the gases of combustion, although they have about twice the specific heat of the iron by weight, reduces the relative quantity of heat, by volume, in contact with the bottom of the boiler to such an extent that the external temperature of the iron where exposed to the fire, may, for ordinary practice, be taken as that of the water within the boiler. Still, notwithstanding the great rapidity of convection, the first result from the intense heat of a flame is to create numerous exceedingly small vesicles of steam (represented by dots on Fig. 1) in contact with the internal surface, which float away from it, and in a short distance are absorbed into the water again, giving out their heat to the water of lower temperature. With active firing these small vesicles will form a turbid cloud, and the closing up of the vesicles, and contact of water with the bottom, will produce a characteristic singing noise which attends boiling, and is particularly noticeable just before the boiling point is reached, when the water at the bottom may be a little above 212°, while that of the mass above may not have attained that temperature. In the case which has been supposed, where the temperature of the ascending current is to be 213°·65, after this cloud of vesicles is absorbed, which will occur within two or three inches of the bottom, the water will become solid again, and rise to the height of 1·2 feet before the pressure upon it will have become sufficiently reduced to allow a bubble of steam to form.

At this height evaporation should commence; it will, however, not do so, because the heat is completely disseminated in the water, and because water has considerable adhesive force or strength of itself (although the particles move upon or slide over each other with much ease, they offer a positive resistance to being separated, which, by the laws of thermodynamics, is measured by the latent heat absorbed), and the water will hold together even when agitated by currents and eddies, as shown in Fig. 1, until relieved of 1 to 2-10ths of a foot more of column pressure; it then begins to exhibit, first a turbidity of small vesicles of steam intermingled with the water, which, ascending with the current and agitated together, will, by joining, form small bubbles of steam. These bubbles will have their internal atmosphere of steam, and their internal surfaces are free to give out steam to this little atmosphere, and these little bubbles, which began to form under about 15 lbs. pressure, will augment in size as the pressure is relieved, at the same time that they are grow-

ing from the formation of steam from the water surrounding them until this formation of steam will have reduced the temperature of the surrounding water to 212°, when the bubbles, and the water enclosing them, will have reached the surface.

Thus, while the circulation was produced by the levity of the column (the heated water), it is greatly promoted and accelerated by the presence of steam in bubbles in the heated mass, and the value of this agency of bubbles can be estimated as follows: A pound of water at 212° is very nearly 28·8 cubic inches or 1-60th of a cubic foot, while a pound of steam at the same temperature is 26·36 cubic feet in volume, or 1,580 times as large as the water from which it was made. The case supposed in Fig. 1 gives 1°·65 of heat as being expended in making steam from what was solid water at the depth of 1·2 feet of 213°·65 temperature. The latent heat of steam at 212° is 966°, and consequently the 1°·65 will make (when applied to a pound of water) 1-580th of a pound of steam, the volume of which will be 26·36-580ths of a cubic foot, or 1,580-580ths = 2·7 times the volume of a pound of water; and the mixed volume of bubbles of steam and water which will come to the surface at the temperature of 212° will be very nearly 3·7 times as great as the volume of water which was solid at 213°·65, lower down in the vessel, and the entire volume of mixed steam and water, above the point of the first formation of steam, will be 2·35 times that of the original water at 213°·65.

Perhaps it may be well to exhibit some rate of evaporation in conjunction with the supposed ebullition, and this can be done by comparison with the ordinary rate of firing of a stationary boiler, which is from 10 to 12 lbs. of coal per square foot of grate per hour, and as each pound of imperfectly consumed coal, on such a grate, yields 9,000 to 10,000 units of heat only, the total efficiency of a square foot of grate becomes 100,000 to 108,000 units of heat per hour, equal to about 30 units per second. If it be assumed that the surface of evaporation be equal to that of the grate, and that either equals one square foot, the volume of steam which will be evolved per second will be 0·8 cubic foot, whence 1-1975th of a pound of water must be converted to steam each second for each square foot of grate, or of surface of evaporation, or, in terms of the volume of water, 0·9 cubic inch of water will be evaporated to steam, and 8·27 of a cubic foot (532 cubic inches) of water will be circulated and part with its

heat each second. Thus it is evident that while the motive power to promote circulation is very great; the usual conditions of a boiler, with a restricted area of surface for evaporation, demand intense activity of circulation. (An example of higher temperature than 212° will be considered further on.)

While this current of steam and water is ascending, a corresponding quantity of water which has lost its heat must descend, and unless provision is made to separate these currents, the conflict will add to the disturbances occasioned by the formation of bubbles. In a vessel or a boiler of considerable dimensions of width as compared with its depth, the conflict will take care of itself, and the velocity of circulation, induced from the expansion of volumes of the heated and partially evaporated mass, will establish a *regime* or equilibrium of action, in the transfer of heat from the fire surface on the one hand, and to the formation of steam on the other; and the steam bubbles will appear at that point in the column of water where the equilibrium may require them as agents for acceleration. If the water surface at the top of the vessel be not large enough (a not very unfrequent occurrence) for the steam to evolve itself in the course of a quiet circulation and surface evaporation; or for the bubble below the surface to develop in size without interfering with the return circulation from the top, it will then be found that a secondary circulation, under pressure from a column of foam, will have been established (Fig. 2), and the supply of return water for the bottom will be derived from below the evaporating surface. The heated return water thus supplied will be again heated at the fire surface to a point higher than before, and the point of elevation where bubbles begin to form will be depressed, to correspond to the elevation of temperature. The bubbles will then develop and approach the surface laden with steam of higher temperature than would be sufficient to preserve a more quiet circulation, and will escape from the surface with some violence; of course a condensation into the disturbed particles of water will ensue, and the result will be the establishment of a strata of foam on the top of the legitimate circulation, and the passing off with the steam of a large quantity of water in the form of mist. This action can go on increasing in violence (with the intensity or extent of surface of the fire as compared to the volume or depth of water to which the fire is applied, taking into account the means of circulation provided) until the return water comes back to the

point of application of heat—the fire surface—at such a temperature, that the amount of heat, there supplied, will generate a bubble of steam at once; when, at this moment, the circulation is interrupted by the tendency of such a bubble to rise within the return current; the next effort of the steam is to eject the mass of water within the vessel convulsively.

Fig.3.

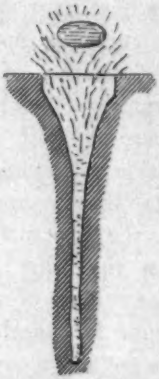

Fig.4.

This phenomena is that of the Geyser (Figs. 3 and 4). In this natural exhibition of a defective water circulation in a heated vessel, the sides of the Geyser tube or vessel are heated as well as the bottom—a condition incident to various steam boilers—and the vessel has a funnel shape, which is not so usual in boiler construction. In the normal state of a Geyser, or a mass of water in the small end of a natural funnel, is in active ebullition from volcanic heat at the bottom, (the constant supply of water being maintained by the dripping of springs in the upper part of the cone quite near the earth's surface); and at or near the time of an eruption, the boiling water is in, or close upon, an equilibrium of circulation and ebullition. By throwing sods, or substances of about the same specific gravity with the water, down the hole, the circulation is impeded, and a quantity of steam of greater pressure than what is due to the column of water is formed, until the mass of water is lifted from the bottom, and the bubble of steam thus evolved at the bottom will augment from the water surrounding it, especially as the piston of water above it, gains in diameter and diminishes in thickness (as the funnel increases in size) *thus reducing the pressure upon the inclosed steam.* The heat of the bottom and walls of the tube will expand the volume of inclosed steam, and evaporate with great celerity the spray or such small quantities of water as may trickle down, and the two causes will preserve the pressure of the steam, beneath the water, to the point necessary for the production of the phenomena, notwithstanding the increase of volume. An eruption of much violence will follow—the whole column of water being expelled with great force, accompanied by the evolvement of steam from the mass of water in the air above.

After the ejection, the fountain of water will have given out a large part of its heat; and if the time of exposure to the air were long enough, the temperature of the ball and spray would fall below 212°, while the Geyser tube would have been entirely relieved from pressure by the expansion and escape of the inclosed steam, so that the mass could fall back into the heated chasm. But not only will scarcely time enough have passed for the water to have divested itself of heat, but the mass which falls will be a broken shower of intermingled steam, air and water; and also the internal surfaces of the tube will have attained, from the absence of water in contact with them, a very high heat, which will be given out to the first small quantities of water which return, generating a large volume of steam, without loss of heat in heating water; and several successive discharges will occur before such degree of quietness is reached, as will allow the water to remain within the funnel; and even after this, much turbulence will be exhibited before the regime of circulation will produce a stable condition of movement.

In my examples, Figs. 1 and 2, the phenomena of ebullition have been shown at the atmospheric pressure, and although it is not intended at this time to carry this discussion beyond the mere elementary exhibitions, yet it may be well to make a similar sketch and computation at higher temperatures.

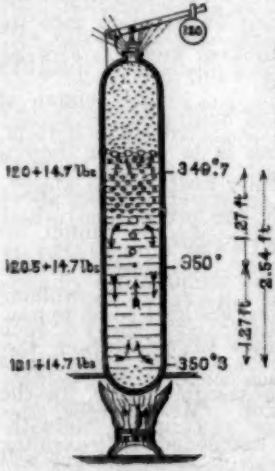

Fig.5

Fig. 5 represents a vessel containing water exposed to the action of heat similar to those shown in Figs. 1 and 2 (ante), except that a permanent pressure of 120 pounds per square inch above the atmosphere is maintained, under which the generation of steam is supposed to be going on. In consequence of the expansion of water at higher temperature, the height of column which represents one pound pressure now becomes 2·54 feet (in place of 2·4 feet), and in consequence of the properties of steam, the difference of temperature corresponding to one-half a pound pressure per square inch becomes 0°·3 (in place of 1°·65). The other figures change as follows: The latent heat at 349°·7 becomes = 870° (in place of at 212° = 966°). A pound

of water has a volume of 30·9 cubic inches (in place of 28·8); a pound of steam has a volume of 3·3 cubic feet (in place of 26·36). The volume of steam as compared to the water from which it is formed at 349°·7 is as 185 to 1 (in place of at 212° as 1,580 to 1). The mixed volume of steam and water at the surface will be but 1·06 times that of the solid water at 1·27 feet below, while the total column of mixed steam and water above the solid water is 1·03 times that of the solid water in this case (in place of 2·35 times at atmospheric pressure). It will be seen from this that the tendency to foam, falls off rapidly as the pressure at which evaporation is permitted, increases—when the bubbles cease to be so large an obstacle to the return circulation; and also that the motive power for circulation gained by the levity of the steam bubbles, falls off with increase of pressure. The manifest effect of this deficiency in inducing circulation, will be to move the point at which the bubbles will begin to form nearer to the fire surface (lower down in the vessel), and to *define the dimensions* of the streams of rising and returning currents. If the rising current is small enough, the bubble of steam may begin to form on the very bottom of the vessel, rise up enlarging in magnitude to the surface, enveloped all the while in a column of water of (in this supposed case) 350°·3 temperature at the bottom—enlarging by relief of pressure, which acts in two ways; first, by permitting expansion, and second, by causing evaporation into its (the bubble's) atmosphere, and finally, the bubble of steam is evolved at the top, quietly at 349°·7.

Fig. 6.

There are two other phenomena of boiling which should be stated here. The first of these is to a great degree experimental. If water is carefully heated in a nicely-formed vessel, Fig. 6, [first taking the precaution to boil it, so as to expel the air which all water absorbs into its volume in quantities relative to the temperature (diminishing with their increase)], applying the heat so as to preclude any disturbance in the course of circulation, the temperature can be elevated much beyond the boiling point without the commencement of ebullition. Mr. Knight, the Secretary of the Franklin Institute, has succeeded in reaching a temperature of 247° in an open vessel, which indicates an internal tension for the water of about 14 lbs. per square inch. Of course the commencement of evaporation under these cir-

cumstances is a convulsive ebullition. The presence of a little broken glass or of particles of any material of splintery form, will prevent the phenomena; and the introduction of any sharp object will almost certainly incite ebullition whenever the boiling point is exceeded.

This peculiar property of heated water seems to be the equilibrium of cohesion (before referred to), which is here manifested to the extreme of instability. The conditions by which it can be displayed are so limited that they cannot be regarded as having a possible existence in any steam boiler, in which there is not the least probability of elevation of the temperature of the water above the boiling point (at any given pressure) by securing that quiescence which all experiments have shown to be demanded for the production of this result.

The second phenomena bears a more important relation to the steam boiler. It has already been shown that water will leave a heated surface, so soon as the temperature of the entire mass has reached that degree where the increment of heat imparted at the surface, upon which it should be brought in contact, will elevate the temperature above the boiling point properly due to the pressure from the mass; and it remains to be stated how a similar repulsion can exist without the temperature of the repelled mass of water being elevated in like degree. If we suppose a heated surface, so hot and so well supplied with heat, that its *radiant heat* will generate steam, from the under surface of a mass of water, of greater tension than the subsisting pressure of the atmosphere or inclosure, together with the pressure proceeding from the weight of the mass, the mass itself will be repelled from the heated surface, and will float upon the vapor emitted. The familiar example is a drop of water upon a flat-iron; the philosophical one is that represented by Fig. 7 and is known as an exhibition of the *spheroidal* condition of water. Water supported in this way must be evidently in very unstable equilibrium, and with the slightest inclination of the heated surface would roll on its vapor to the lowest point, and a capsule or saucer-shaped vessel is therefore indispensable to retain it.

Fig. 7.

In the course of the experiment very little heat is imparted to the ball of water, the radiant heat being spent mainly upon the under surface, while that which passes through this surface shines through the water as light shines through glass; thus, only the film, so to speak, of the under surface is heated, and much if not most of this heat upon

the surface is at once expended in generation of steam. The little heat that is imparted to the water at the under surface, in place of establishing a circulation of water within the ball, simply disturbs the centre of gravity, and induces the whole mass to roll over and allow its heavier (colder) side to find its equilibrium at the bottom; and in the operation, under the conditions stated, a spheroidal shape is assumed by the body of water.

Investigations have shown that when the surface of the vessel is heated to about 380° Fah. a spheroid of water of about two inches of thickness will be repelled and constantly supported, while the temperature of the water (with the air in a summer-hygrometric condition?) will be about 206°, or 6° below the boiling point (Boutigny).

This recital of what constitutes the spheroidal condition (so-called) of water has been made, with so much explicitness, in order to render it apparent that it is merely a simple consequence to the laws of transmission of heat from a surface to water, and not an occult property in any sense. The statement of importance in boiler construction is, that at some temperature a heated surface will repel water, and that once repelled the surface will cease to impart as much heat as before, and the repelled mass of water can become of much lower temperature than it must have had if the contact had been preserved, and these truths apply to water under pressure (atmospheric or other), and to any height of column of water upon or above the heated surface, a relative temperature being accepted for the various conditions.

Whenever the water has been once repelled from a fire surface or plate, the temperature of that surface will increase with great rapidity, and the limit of this temperature of a plate it is difficult to fix. It is certain that where there are gaseous bodies on either side of a plate, the temperature of which bodies are known, the temperature of the plate itself will be a function of the capacity for heat of the two gaseous bodies in opposite contact; but even this complex law for obtaining the heat of a plate from which water has been repelled fails in the case of the fire-box of a boiler, where half the heat from the flame is radiant heat which is absorbed into the plates of the fire-box at an unknown temperature of intensity, although the quantity of heat may be well established. But I think it safe to assert that in less than one minute's time the temperature of a 5-16 inch plate in a fire box from which water has been repelled, will become over 1,000°

Fah., and the plate will be materially reduced in strength to withstand the internal pressure.

I have not attempted to complete this application of principles to the locomotive boiler; in fact, I feel the deficiency of my elementary remarks in their want of comprehensive statement of circulation, where the return takes place from the back instead of downwards, as I have discussed; but I present these considerations as showing the direction of inquiry to be followed in the attempt to account for failures of fire-box sheets or of tubes, whenever the evidence of overheating presents itself. In such cases, I have little question that obstructed circulation and inadequate water-space have more to do with accidents than the quality or nature of the material of the plates. . . . .

Mr. Briggs quoted an instance of the failure of some tubes in a class of locomotives constructed ten or twelve years since, for the Illinois Central Railroad. In this case, a cluster of seven 2-inch tubes, which were located about one foot down, upon the tube sheet, in its middle, in several engines of the same class, collapsed about one to two feet in front of the sheet. A sample of one of the collapsed tubes, which was furnished the speaker by Mr. Hayes of the Illinois Central Railroad at the time, showed a cup-shape introversion without rupture of about six inches in length, the upper side of the tube having been depressed into the lower one completely. Of course the tube had been above red heat when this occurred. The remedy was understood to have been the removal of one or two vertical rows of tubes to allow the water to circulate.

Notes on Ventilation.—Some experiments made recently by Theron Skeel, C.E., and Mr. Carl. W. Nason, at Doct. Hall's church, New York City, have given the following resulting performances of a ventilating fan :

	Number of Experiment. I.	II.
Revolutions of fan per minute	66·7	110·
Difference of atmospheric pressure between inlet and outlet chambers, in inches of water .	0·145	0·400
Velocity of air in duct beyond the fan, in feet per minute, as indicated by an anemometer .	484	750
Cubic feet delivered per minute . .	9900	15370

The Fan* employed is of the kind most generally in use in ventilation of buildings in the U. S. at the present time, having been first introduced at the U.S. Capitol at Washington, in 1857 (the earliest in use was, during the same year, at the Academy of Music, Philadelphia). It is a disc upon a shaft, with blades attached upon one side, and extending to the outer periphery, rotating in front of a circular mouth or opening in a wall, or fan-side. The mouth or opening is either directly from the external air, or from a passage of ample size which leads therefrom, and the ring of discharge at the periphery of the disc is open for the escape of air in all directions to the "*air chamber*," in which the disc revolves. From the air chamber a "*duct*" is lead to the points of distribution or delivery of air in the building.

This Fan is 7 feet in diameter of disc—8 inches wide at the tips of the blades; 5 feet in diameter of mouth—15 inches width of the blades at the mouth; having $\frac{3}{8}$ inch clearance between the edges of the blades and the wall or fan-side; with an area of 19 square feet at the mouth, and 15 square feet at the periphery (the actual area for passage of air at the tips of the blades when delivering maximum quantity = 10·9 feet only), while the area of the duct or passage leading from the air chamber is $20\frac{1}{4}$ square feet.

It is nearly impossible to connect the observed pressure of the column of air derived from a ventilating fan, with the velocity or corresponding quantity of air passing through it. Were the fan entirely at rest, and the passages leading to it, as well as the duct leading from it, open, the whole being in the basement of a building which is heated in any way; there would be sucked through it, without the indication of but the slightest difference of pressure between the inlet and outlet "chambers," a quantity of air varying with the difference of temperature without and within the building, the height of the building, the resistance of the ducts and registers of delivery, and the freedom allowed for escape of heated air at the top of the building. The only reliable standard of measurement of effect or efficiency, is the anemometer, to be applied as a test under the differing conditions of the season or atmosphere. The purpose of a fan in ventilating of buildings, is to insure a definite supply of air at all times, with a satisfactory distribution in all parts of a room. In

* A full description of this species of fan will be found in the Proc. Institution of Civil Engineers. Vol. XXX. 1869-70. Part II, pp. 276, *et seq.*

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cold weather its function is to measure out the supply, and place the building under such pressure that no leakages of cold air at cracks shall occur. In more moderate and warmer weather its end is to establish a circulation which would otherwise become dormant. The quantity of air resulting from a given velocity will be found to vary materially with conditions external to the fan itself.

Referring to experiment No. 1, when 9900 cubic feet of air was supplied, it is stated that at the end of a service of 1½ hours, with 1400 people in the church, there was found to be a proportion of $C O_2$* in the air, of 12½ to 10,000. The audience room which was thus supplied, had a capacity of nearly 480,000 cubic feet of air. If it be supposed that the air in the room was fresh, and had the normal quantity of 3½ parts of $C O_2$ per 10,000, it is possible to verify, or at least compare the result with the usual allowance for vitiation of air by the occupants. The 9900 cubic feet per minute for 90 minutes give 891,000 cubic of air supplied. This was expelled at the beginning of the session as fresh air, with 3½ parts of $C O_2$ per 10,000, but became vitiated to 12½ parts per 10,000 at the end, whence the expelled air carried away $\frac{891000}{10000} \times \frac{12\frac{1}{2}-3\frac{1}{2}}{2} = 401$ cubic feet of $C O_2$. The 480,000 cubic feet of contents of the room had also been exchanged, until it contained 12½ parts of $C O_2$ per 10,000 in lieu of of 3½ parts of $C O_2$, when it had acquired $\frac{480000}{10000} \times (12\frac{1}{2} - 3\frac{1}{2}) = 432$ cubic feet. The total of $C O_2$ which had been produced by the respiration of 1400 people in one a half hours, equal to 2100 people in one hour, is $401 + 432 = 833$ cubic feet $C O_2$.

∴ The respiration of each person per hour = 0·4 cubic feet $C O_2$.

The best authorities give 0·5 to 0·6, and this result is in quite satisfactory correspondence, when it is considered that much carbonic acid may have been diffused at leaks and cracks at the doors and windows, and much more at the passages of efflux, where it would flow out more rapidly than the current of escaping air. Beside, the allowance of 0·5 to 0·6 per individual is an average of persons in moderate exercise, in place of at rest in a room.

Accepting the 833 cubic feet as the quantity of $C O_2$ emitted by the 1400 persons in 1½ hours, and applying the computation in the reverse way to experiment II, it would follow that 10·6 volumes of $C O_2$ per 10,000 would be the resulting vitiation. Good theoretic ventilation would assume 56,000 cubic feet of air per minute as *desirable* for 1400 people.

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* $C O_2$ is the chemical notation for carbonic acid gas.

GAS WORKS ENGINEERING.

By Robert Briggs, C. E.

[Continued from Vol. cii, page 40.]

"The '*hydraulic main*' is a long trough-pipe, with a covered flat top; it is about two feet wide and three feet deep, and runs the whole length of each *setting*, resting over the front part of it. The leg of the bridge-pipe (∩), which joins the cover of the hydraulic main, enters into it for half the depth, or one and a half feet, and is called the '*dip-pipe*.' The hydraulic main is permitted to fill a little more than half full of tar and ammoniacal liquor (mostly tar, as the ammoniacal liquor runs out first over the bridge at the end of the hydraulic main), and the end of the dip-pipe is thus immersed (*sealed*) by the tar, from one-half inch; and any gas which passes up the stand-pipe, over the bridge-pipe and down the dip-pipe, must bubble up through one-half inch to one inch of tar, to get into the upper part of the hydraulic main. The chief purpose of the hydraulic main is to prevent an escape of gas backwards, down the stand-pipes, when a retort-lid is removed; and this purpose is affected by the pressure of the gas in the hydraulic main, which, pressing on the liquor outside of the dip-pipe of an open retort, lifts up a column on its inside, and stops off the flow of any gas; but the stand-pipes and the hydraulic main answer the further purpose of a hot condenser, giving time enough and surface enough for most of the tar to separate out of the crude gas in them, in place of going over to be cooled together; when the tar would be likely to extract the luminous gases or vapors, very completely. Beside, the first oils which are made in the beginning of the process of distillation are condensed in the stand-pipe, and run back into the retort to be destructively distilled afterwards.

"There collects in the stand-pipes, and runs down at the last end of the process, a small quantity of stiff tar, which lodges in the bottom of the mouth-piece; this is usually collected (scraped up) and put into the next charge of coal. Some of this coal tar had been thrown out with the coke on the occasion of one of my visits to the gas-works, and produced at the coke-heap the characteristic odor.

"[§ § *Two.*] At the Market street works, the tar and ammoniacal liquor are conveyed, from the ends of the six hydraulic mains by pipes

nowhere open to the air, into a large tar-well, which is a vat formed by a liquor-tight cellar of one of the buildings used for storage of lids, castings, and materials of various kinds; the floor, which forms the cover or top of this vat is brick arches, covered by iron braces. This vat seemed to be about fifty by eighteen feet, by seventeen feet deep, inside measure, and in it these offensive by-products are thoroughly and satisfactorily isolated. The tar having settled and become free of ammoniacal liquor, is then removed by a steam-pump, and taken across, as wanted, to a temporary building, in which is placed some distilling apparatus for recovery of the oils and separation of the pitch.

"Upon the whole, this coal-tar distillery apparatus and its mode of working appeared to me to be quite satisfactory. Some of the vats ought to be closed better than they now are, and some other precautions should be taken to prevent nuisance of smell from spilled oils; but I must regard this treatment on the spot to be far more likely to remove causes for complaint than any mode of removal possible to make. I think it would be impossible to convey the tar away by pipes or otherwise, without the risk, and almost certainty, of greater annoyance to the public than now exists.

"At a distance of twenty feet from the tar-building no distinctive odor was perceptible to the nostrils (which, however, had their power of smell vitiated to some degree by the odor of naphthaline and ammoniacal liquor obtained at the condenser-house).

"The ammoniacal liquor was said to be drawn off from above the tar and used afterwards in washing the gas, and will be referred to again in the course of this statement.

"[§§ *Three.*] The gas is now taken from the hydraulic mains by large pipes (sixteen inches in diameter, I believe), and these pipes pass down under the ground into one large main pipe of thirty-six inches diameter, which passes underground, also, to the house for condensing and washing the gas, and by suitable branches and connections supplies the gas—first, to three '*condensers*' and afterwards to three '*washers;*' all the outlets from the washers being joined again into a thirty-six inch main-pipe, which proceeds over to the 'purifiers.'

"The condensers are long and high constructions (or boxes) of cast iron, with pilasters and architectural ornamentatation, and measure about thirty-six feet long by five feet wide on the floor, by

thirteen to fourteen feet high. These condenser boxes are altogether closed up, and are in three separate parts horizontally; there being one flat plate partition about one and a half feet from the bottom and another about one and a half feet from the top, leaving eleven feet for the height of the middle part. In this middle part are stood up, between and joining together the flat partitions, a large number (it is said two hundred and eighty-eight to each condenser) of pipes, which are thus each eleven feet in length, and they are four inches internal diameter; and, as water-tight joints are made between the bottom partition plate and the ends of the pipes, the middle part can be, and is, filled with water, which surrounds the upright pipes. The top and bottom spaces (above and below the pipe ends) are, also, divided by cross partitions, so that when the gas enters at the bottom at one end of a condenser it will pass up thirty-six of these upright pipes and down the next thirty-six, and so on until its gets to the end of the series, when it will pass out to the main pipe leading to the washer.

"It follows that in this passage of the warm gas, in contact with the cooled sides of the pipes, it will be cooled itself, and will have had the ammoniacal liquor nearly all condensed, and the most of the floating tar will have been abstracted. The liquor runs down into the bottom of the lower division of the condenser, and is from thence drawn off by suitable drips.

"It was formerly customary to arrange a condenser with pipes exposed to the open air; but a much greater extent of surface was needed to effect the same purpose, and the condensation was imperfectly done in hot weather and overdone in cold weather, when the cold ammoniacal liquor would absorb the luminants from the gas. The 'water-surface' condenser here used, is in accordance with the best established practice of to-day.

"The liquor is led away by pipes to some vat or tank, but at the condenser-house of the Market street works the drips or seals are either open, or by some neglect the liquor is permitted to be exposed to the air, and the odor of various gas effluvias is excessively offensive, and disseminates all over the place and beyond the limits of the works.

"Comparing this condition of things with what I found in similar establishments in New York last week, I can state that at the Manhattan or New York Mutual Gas-works only the slightest odor in the condenser-room was to be perceived.

"After the gas leaves the condenser, it goes next to the washer. The washers are boxes of similar external appearance to the condenser, only that they are about two feet less in external height, and measure about three and one-half feet in width. The internal divisions differ from those described for the condenser entirely, being merely a number of vertical plates, which divide each washer into thirty-six upright spaces, so that the gas can go up one and down another alternately, until it has passed up and down the whole length of the washer. In each of these spaces are placed one or two jets, which generally discharge little streams of water upwards, and in its descent as a rain, picks up and absorbs the ammoniacal vapors and washes them away. The water of washing is, in such cases, usually discharged into a sewer or stream. In place of using water for the jets at the Market street works, the ammoniacal liquor which separates from the tar, together with that condensed in the condenser, is now pumped up to a vat and used for this purpose. It is clained that this water will sufficiently purify the gas from ammonia, and that it can be used over and over, until it acquires a suitable strength to be treated for manufacture of commercial ammonia product. I am not prepared to deny the possibility of this result, but am also not prepared to believe it, as it is not in accordance with any practice which I have ever seen, and from the behavior of gas delivered in my own residence, I do not think the gas as well purified from ammonia as it might be, although certainly not very imperfect in this respect. It is recognized by all gas-makers that the use of much water impairs the luminous efficiency of gas, quite as much as the removal of ammonium compounds improve it, and it is consequently the practice of intelligent managers to use as little water as possible. To effect this purpose, the most approved practice demands a shelf-washer; which is an arrangement of high boxes in which shelves are placed overlapping each other; upon these shelves the water is trickled, so as to keep the entire surface wet, and the gas is made to zigzag up the tier of shelves; several repetitions of this practice are followed, and the gas is worked with a minimum quantity of water.

"Notes taken by me at the Pagoda Works of the Birmingham and Staffordshire Gas Company, Hugh Young, manager, in January, 1870, describe the 'washer in use there, for twenty-four inch mains, to be six compartments, six feet square by sixteen feet high, each with six shelves; fresh water is used in one of these compartments, which is

pumped over and over for three hours, when it is changed to the next compartment, and so on until, at the end of eighteen hours, the liquor will have attained the requisite density of manufacturing purposes. The washing was followed by two small purifiers, sixteen feet by sixteen feet, with sawdust damped with weak sulphuric acid, one of which was changed each three weeks, and the ammonia tests, for constant exposure of one month duration, were exhibited and shown to be perfect.'

"This example may be accepted as the best usage of to-day in the United Kingdom for treating gas for ammonia.

"At the Market street works, all the ammoniacal liquor, after passing through the washers and being concentrated, is now run into tanks; and again elevated so as to form a head for the flow through pipes under the streets, to the chemical laboratory of Henry Bowers, on Washington avenue, about one mile distant. This arrangement was said to have been effected for the first time six months since, and, except some objectionable exposure of the liquor at the works, is much better than wasting this vile compound into the river, as was formerly practiced. Of course the utmost care is demanded that the pipe used for conveying it shall be positively tight and free from leaks.

"The pipes and connecting branches about condensers and washers are provided with numerous stop-valves, which admit of such control as will direct the gas through any of them, or 'by pass' them all, as desired.

"All the buildings and apparatus described to this point are located on the square of ground north of Market street and west of Twenty-fourth street, with the Schuylkill river for the western and Filbert street for its northern boundary.

"[§§ *Four.*] The gas after leaving the washer is carried by a thirty-six inch main-pipe across the line of Market street, below ground, in the thoroughfare under the eastern span of Market Street Bridge (which crosses above the wharf and yard level of the gas-works), and is conveyed to the purifying houses; the latter being located about half-way between Market and Chesnut streets, near the river. At the northern side of the purifiying house are placed engines and exhausters for moving the gas. These were not examined by me, but I am disposed to think that they differ in no essential way from the same parts of gas apparatus in other works.

(To be continued.)

CONTINUOUS GIRDERS AND DRAW SPANS.

By A. Jay DuBois, C. E., Ph. D., Prof. Civil and Mechanical Engineering, Lehigh University, Bethlehem, Pa.

[Continued from Vol. cii, page 32.]

V. EXAMPLE OF PIVOT SPAN.

In Fig. 7 we have represented a draw, the two outer spans being each 40 ft., the centre span $B\ C = 20$ ft.; centre height at B and $C = 10$ ft.; end height, 6 ft.; panel length, 10 ft. Two systems of triangulation, as shown in the Fig. We take the live load at 1 ton per ft. per truss, or 10 tons at each apex. Dead load we assume *one-half* of this, or 5 tons per apex. Our proportions are, of course, taken for the sake of illustration merely, and not as an example of actual practice. All the points necessary to be brought out are, however, illustrated as well as by a much longer span and more usual proportions.

As to the construction of the truss, it is to be observed that the end verticals must take compression only, and *not tension*. This is easily effected in practice, and is necessary to prevent ambiguity as to the way in which the strains may go. A negative reaction (downward), or end shear, might otherwise cause either tension in 12 and compression in F, or else tension in 15 and compression in 56 and tension in A. If, however, 15 cannot take tension, we have but one course for the strains and the problem is determinate. For similar reasons also, we must construct the centre span so that the diagonals take *tension only*, and the three verticals *compression only*. All other pieces may take both tension or compression indifferently. These points as to construction being settled, we proceed first to determine the reactions.

1*st*. *Reactions*.

We shall consider the case of the *tipper*, or secondary central span, as this case, we will suppose, approaches most nearly the true state of things. The method for four fixed supports is, of course, precisely similar, only taking the formulæ already given for that case. The less the span $B\ C$ the nearer the case approaches to that

of three fixed supports, and where $B\ C$ is zero, or n is zero, the formulæ are the same as for two equal spans.

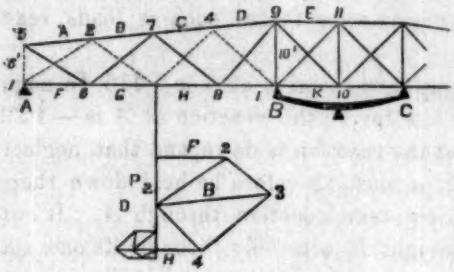
We must first put our formulæ into proper shape for use in the particular case under consideration. Thus $l = 40$, $n\ l = 20$, hence $n = \frac{1}{2}$ and $H = \frac{35}{4}$; $k = \frac{a}{40}$ where a has for each apex load the successive values 10, 20, 30, etc., for $P_1\ P_2$, etc., or k is successively $\frac{1}{4}$, $\frac{2}{4}$, $\frac{3}{4}$. Our equations are then, after reduction.

$$R_A = \frac{5}{35}\ [70 - 73\ k + 10\ k^3],$$

$$R_B = R_C = \frac{5}{35}\ [45\ k - 10\ k^3],$$

$$R_D = \frac{5}{35}\ [10\ k^3 - 17\ k],$$

Fig 7



Now the denominator of k is always 4, of k^3 always 64; the numerator only changing according to the position of the weight. These equations can then be written:

$$R_A = \frac{1}{224}\ [2240 - 584\ a + 5\ a^3],$$

$$R_B = R_C = \frac{5}{224}\ [72\ a - a^3],$$

$$R_D = \frac{1}{224}\ [5\ a^3 - 136\ a],$$

where a has the value 1, 2, 3, etc., for $P_1\ P_2\ P_3$, etc.

These, then, are the practical formulæ for the present case, and from them we can easily find the reactions for the apex loads of 10 tons each.

Thus for P_1 we make $a = 1$ and find at once $R_A = 7{\cdot}415$ tons $R_B = R_C = 1.58$ and $R_D = -\ 0.584$ tons.

For P_2, make $a = 2$ and then $R_A = 4{\cdot}964$, $R_B = R_C = 3{\cdot}035$, $R_D = -\ 1{\cdot}035$.

For P_3, make $a = 3$, and $R_A = 2{\cdot}78$, $R^B = R_C = 4{\cdot}22$, $R_D = -$ 1 22.

Loads upon the span BC we suppose to rest directly upon the turn table. For the first load to the right of C, *viz.*, P_4, the reactions at A and B are the same as for P_3 at D and C already found. For the next load P_5, reactions at A and B are the same as for P_2 at D and C. For P_6 at A and B, same as for P_1 at D and C, etc. We thus know the reactions at A and B, due to every apex load in either end span, and can now proceed to find the strains. The formulæ for reactions, it will be observed, are very simple for any particular case.

2*d*. *Calculation of Strains.*

We have only to apply the method of moments, and the work is so simple, that an example or two will suffice. Conceive a section entirely through the truss, which cuts only three strained pieces. Take the intersection of two of these as a centre of moments. Then the moment of the strain in the third must be balanced by the sum of the moments of the known exterior forces, such as loads, reactions, etc.

Take P_1 for example; its upward reaction at A is 7·415, [a negative reaction acts *down*. Thus for P_4 the reaction at A is —1·22. The minus sign indicates that the reaction is down, and that, neglecting the dead weight of girder, it must therefore be held down there. The tendency is to rise]. Now take a section through A. It cuts four pieces. But since the weight P_1 acts only through its *own system of diagonals* (full in Fig.), only these are strained. The point of moments for A is then at 6, *the intersection of the other two strained pieces*. The strain then in $A \times$ by its lever arm $= 7{\cdot}415 \times 10$. The lever arm of A with reference to 6 is from the proportions of the figure, easily found to be 6·965, hence $A \times 6{\cdot}965 = 7{\cdot}415 \times 10$, or $A = 10{\cdot}64$ tons *compression* because the upward reaction, acting to revolve the section round apex 6, tends to compress A. This strain evidently acts through both A and B, since both these flanges are included by the diagonals of the system for P_1. Hence $B = +10{\cdot}64$ tons also. Again, for flanges C and D, 78 is the strained diagonal, 8 the point of moments, and the same reaction acts now with lever arm of 30 to cause compression in C and D, while the force P_1 itself acts with lever arm 20 to cause tension. We have then $C \times 8{\cdot}955 = 7{\cdot}415 \times 30 - 10 \times 20$ or $C = D = 2\,5$ tons compression.

Now we come to the centre span, and must carefully observe the following points. Since D has been found compression for P_1, diag-

onal 89 must be in tension. If there were no vertical strut at B, we should then have compression along diagonal 9 10. But this diagonal by construction *cannot take compression;* it therefore does not act, and the strained pieces cut by a section through E are then, E, K and B 11, which gives us the centre of moments for strain in E at B. Observe, that without the vertical, we should have had 10 for the centre of moments; or even *with* the vertical, had D been found in tension, as may often happen, 89 would have been compression. There would in that case have been no strain in the vertical, since it cannot take tension, and we should then have 9 10 strained and the centre of moments, therefore at 10. Attention to the above is necessary in order to properly pass from the span A B into the middle span.

We have then for strain in E, since R_B passes through the centre of moment B, and therefore its lever arm is zero, $E \times 10 = 7{\cdot}415 \times 40 - 10 \times 30$ or $E = -0{\cdot}34$. The minus sign indicates tension, since the moment of P_1 overbalances that of the reaction. If the centre of moments had been at 10, we might either have taken the moments of R_A, P_1 and R_B, or, what is the same thing, the moment *of the shear just to the right* of B alone.

The lower flanges are found in precisely similar manner. The centre of moments for G and H is 7, and hence $G \times 8 = -7{\cdot}415 \times 20 + 10 \times 10$ or $G = -6{\cdot}04$, and so on.

For the diagonals we have only to take the intersection of the upper and lower flanges as a centre of moments for each, and find the lever arm for each. This intersection is, of course, easily found from the known proportions of the figure. Thus 4 : 40 : : 10 : 100. It is therefore 100 ft. left of B, or 60 ft. left of A. For any diagonal, as 34, we find the angle with the horizontal nearly 42°. Its lever arm is then 80 sin 42° = 53·5 feet.

For the weight P_2, for instance, the reaction at A is 4·964 tons, P_2 being 10, and we have, then, strain in 3 4 $\times$ 53·5 = 10 $\times$ 80 — 4·964 $\times$ 60 = +502·16. The resultant rotation is then positive, that is from left to right. If the truss were cut through at C and H then, the point 3 would sink, and 4 rise, and 3 4 is therefore in tension, and $= \frac{502{\cdot}16}{53{\cdot}5} = -9{\cdot}38$ tons. This is sufficient to illustrate the calculation of strains. We have only to remark that in practice, having found the reactions, we can easily *diagram* the strains for each apex

load, as shown in the figure, and check our accuracy by calculating the last flange thus found. This may often save much labor in long spans, in the finding of lever arms, angles of inclination, etc. (See for this method of diagram, "Graphical and Analytical Determination of Strains in a Roof Truss," in April number of this JOURNAL. Also, "Elements of Graphical Statics.") This method of diagram may of course be applied to the continuous girder also.

We can now tabulate the strains for each apex load in every piece.

3*d*. *Tabulation of Strains.*

Thus for flanges—bridge shut—we have:

	A	B	C	D	E	F	G	H	I	K
P_1	+10·64	+10·64	+2·5	+2·5	−0·34	0	−6·04	−6·04	+0·34	−1·34
P_2	0	+12·74	+12·47	−0·14	−0·14	−7·1	−7·1	−5·32	−5·32	+2·14
P_3	+3·9	+3·9	+9·31	+9·31	+1·12	0	−6·95	−6·95	−1·12	+1·88
P_4	0	−3·1	−3·1	−4·88	−4·88	+1·74	+1·74	+4·06	+4·06	+1·88
P_5	0	−2·6	−2·6	−4·4	−4·14	+1·46	+1·46	+3·45	+3·45	+2·14
P_6	0	−1·4	−1·4	−2·34	−2·34	+0·83	+0·83	+1·95	+1·95	+1·34
Total Strains in Flanges	+14·54	+27·01	+24·28	+11·81	+1·12	+4·03	+4·03	+9·8	+9·4	+9·38
		−7·1	−7·1	−11·76	−11·84	−7·1	−20·1	−18·3	−6·4	−1·34

From what has been already said, no difficulty can be found in finding the strains due to the *dead load* (5 tons per apex) *when the bridge is open.*

	A	*B*	*C*	*D*	*E*	*F*	*G*	*H*	*I*	*K*
Thus	0	−6·2	−17·4	−31·2	−40·0	+3·6	+9·7	+20·1	+33·8	+40·0

If now, we suppose the centre supports *raised*, so that the ends just bear, then these strains act *even when the bridge is shut.* The live load strains then act in combination with these, and it is therefore easy to find the maximum strain which can ever occur in any piece. It is also easy to deduce directly from our tables the strains due to any other loads, such as snow, etc., without calculation, by simply taking proportional parts of the apex load strains already found. The complete calculation of a draw span offers, then, no special difficulty, whether we treat it as three spans, as *tipper*, or as two spans. The above includes then, in brief, every case of draw span or of con-

tinuous girder over level supports, and we can now pass on to our general formulæ, upon which the data for all these calculations depend.

VI. GENERAL FORMULÆ FOR SHEARS AND MOMENTS.

The following formulæ include every case of level supports, whatever the number or lengths of spans, for a load anywhere in any span, or for a load uniform over whole of any one span. They were first deduced by Mansfield Merriman, C.E., Assistant in Civil Eng., in the Sheffield Scientific School of Yale College, and are, as we shall see, wonderfully compact, simple and comprehensive. They give us, as already shown, exactly what we need in any case, viz., the outer forces, and in such a condensed form that the engineer can copy them upon a couple of pages of his note-book. If, then, he understands the simple method of calculation already noticed in Article 3, he can solve with ease and perfect accuracy problems which have hitherto been considered "impossible by reason of their complicity," and as "tasking the powers of the best mathematicians."

1. *Notation.*

It is of course essential to be thoroughly familiar with the notation adopted, and the following should therefore be noted with care:

We denote the whole number of spans by s, hence the whole number of supports is $s+1$, numbered from *left to right.*

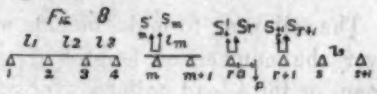
The number of *any* support in general, always from left, is m. When a load is in any span, the *supports of that span* are always r and $r+1$, left and right.

The length of any span is denoted by l, with a subscrit showing what span it is. Thus, l_1 l_2 . . . l_s, l_m, l_r, are, respectively, the first, second and last spans, any span in general, and the loaded span.

A concentrated load is indicated by P; its distance from the nearest *left* hand support is always a; the ratio of a to the length of loaded span l_r is k, or $k = \frac{a}{l_r}$.

Moments and shears are denoted, like lengths of spans, by subscrits. Thus, M_m is any moment depending on the value of m. M_r and M_{r+1} are the moments at ends of loaded spans. The shear to the *right of any support* is S, thus S_m, S_r and S_{r+1}. The shear just to the *left* of any support is indicated by a prime. Thus S_r and S'_{r+1} are the shears just to right and left of left and right supports

of loaded span, Other symbols which we use, as in the preceding Article, we have already used the letter H, for expressions which occur frequently, will be best explained as we have occasion to introduce them. By reference to the following Fig. 8, the reader can familiarize himself with the above notation, and will then find no difficulty in understanding and using the following formulæ. The correctness of these formulæ he must take "on faith." For their demonstration we refer him to the "Elements of Graphical Statics." He can also check them by deducing the various special cases given in most works upon Theory of Flexure, such as "beam fixed horizontally at one end, supported at other," etc., as will be explained hereafter. A few simple experiments on a small scale may also be easily made, and will serve to give confidence in the practical accuracy of the formulæ.



2. *Formulæ.*

(*A.*) *Shear at any support, right and left.*

For the *loaded span*, we have on the right of the left support

$$S_r = \frac{M_r - M_{r+1}}{l_r} + q,$$

and on the left of the right support

$$S'_{r+1} = \frac{M_{r+1} - M_r}{l_r} + q',$$

where $q = P(1-k)$ for a concentrated load, and $q = \frac{wl_r}{2}$ for a uniform load, w being the load per unit of length, and $q' = P\,k$ for concentrated, and $q' = \frac{wl_r}{2}$ for uniform load.

For an *unloaded* span at the right of any left support whose number counted from the left is m, we have

$$S_m = \frac{M_m - M_{m+1}}{l_m},$$

and at left of any right support,

$$S'_m = \frac{M_m - M_{m-1}}{l_{m-1}}.$$

The "*reaction*" at any support is $R_m = S'_m + S_m$.

These formulæ for the shears are perfectly general and very simple. In general, we need to know only the shear at right of any support,

viz., the left support of the span in which the strains are required. By substituting the proper value for m or r, we can then find the shear, *provided we know the moments at two successive supports.* The whole case then reduces to finding the moments themselves.

(*B.*) *Moment at any support.*

To find the moments, we make use of certain auxiliary quantities represented by A, B, c, and d, whose values we shall give afterwards. The general expressions for the moments themselves are when $m < r+1$,

$$M_m = c_m \frac{A\, d_{s-r+2} + B d_{s-r+1}}{l_2\, d_{s-1} + 2\,(l_1+l_2)\, d_s};$$

when $m > r$,

$$M_m = d_{s-m+2} \frac{A\, c_r + B c_{r+1}}{l_{s-1}\, c_{s-1} + 2\,(l_s+l_{s-1})\, c_s};$$

now, for the auxiliary quantities, we have $A = P\, l_r^2\, (2k - 3k^2 + k^3)$, and $B = P l_r^2\, (k - k^3)$ for *concentrated load*, where k is always $\frac{a}{l_r}$, and $A = B = \frac{1}{4} w\, l_r^3$ for uniform load of w, per unit of length entirely covering any span l_r.

Also for c and d we have the following values :

$c_1 = 0.$ $\qquad$ $d_1 = 0.$

$c_2 = 1.$ $\qquad$ $d_2 = 1.$

$$c_3 = -\frac{2\,(l_1 + l_2)}{l_2}. \qquad d_3 = -2\,\frac{l_s + l_{s-1}}{l_{s-1}}.$$

$$c_4 = -2\,c_3\,\frac{(l_2 + l_3)}{l_3} - c_2\,\frac{l_2}{l_3}. \qquad d_4 = -2\,d_3\,\frac{l_{s-1} + l_{s-2}}{l_{s-2}} - d_2\,\frac{l_{s-1}}{l_{s-2}}.$$

$$c_5 = -2\,c_4\,\frac{(l_3 + l_4)}{l_4} - c_3\,\frac{l_3}{l_4}. \qquad d_5 = -2\,d_4\,\frac{l_{s-2} + l_{s-3}}{l_{s-3}} - d_3\,\frac{l_{s-2}}{l_{s+3}}.$$

and so on, for as many as may be desired, or generally

$$c_m = -2\,c_{m-1}\left(\frac{l_{m-2} + l_{m-1}}{l_{m-1}}\right) - c_{m-2}\left(\frac{l_{m-2}}{l_{m-1}}\right).$$

and so on, for as many as may be desired, or generally

$$d_m = -2\,d_{m-1}\,\frac{l_{s-m+3} + l_{s-m+2}}{l_{s-m+2}} - d_{m-2}\,\frac{l_{s-m+3}}{l_{s-m+2}}.$$

For *all spans equal*, these numbers c and d become equal and are successively 0, 1, —4, +15, —56, +209, —780, etc., alternating in sign and each one equal to four times the preceding minus the next preceding. These are the well known "Clapeyronian numbers,"

the properties of which were first made known by *Clapeyron* (*Comptes Rendus*, 1857). They are, it will be seen, merely particular cases of the more general expressions above, first deduced by *Merriman*, and which hold good for *any* lengths of spans.

VII. EXAMPLES OF USE OF THE FORMULÆ.

1. *A girder continuous over three equidistant supports A B and C, has a weight P in first span at distance a from left end. What are the moments? What are the shears at the supports?*

Here we have $s = 2$, also $r = 1$, and $l_1 = l_2 = l$, hence $d_1 = c_1 = 0$, $d_2 = c_2 = 1$, $d_3 = c_3 = -4$, $d_4 = c_4 = +15$, etc.

We have then for the moments, $M_1 = 0$, since $c_m = c_1 = 0$, $M_2 = d_2 \dfrac{Ac_1 + Bc_2}{l c_1 + 2(l+l) c_2} = \dfrac{B}{4l} = \dfrac{Pl}{4}(k - k_3)$ and $M_3 = 0$, since $d_{s-m+2} = d_1 = 0$. For the shears, therefore, $S_r = S_1 = S_A = \dfrac{M_r - M_{r+1}}{l} + q = \dfrac{M_1 - M_2}{l} + P(1-k) = \dfrac{-M_2}{l} + P(1-k)$, or $S_A = \dfrac{P}{4}(4 - 5k + k^3)$, or putting $k = \dfrac{a}{l}$, $S_A = \dfrac{P}{4l^3}(4l^3 - 5l^2 a + a^3)$ precisely the same as already given for this case in Art. 4.

For S'_B, we have $S'_2 = S'_{r+1} = S'_B = \dfrac{M_2 - M_1}{l} + q' = \dfrac{M_2}{l} + Pk = \dfrac{P}{4}(5k - k^3)$.

For S_B, we have $S_2 = S_{r+1} = S_B = \dfrac{M_2 - M_3}{l} = \dfrac{M_2}{l} = \dfrac{P}{4}(k - k^3)$. Now the *reaction* at B, or $R_B = S'_B + S_B = \dfrac{P}{4}(6k - 2k^3) = \dfrac{P}{2}(3k - k^3) = \dfrac{P}{2l^3}(3l^2 a - a^3)$, precisely as already given. For S'_C we have $m = 3$, or, $S'_C = S'_3 = \dfrac{M_3 - M_2}{l} = \dfrac{-M_2}{l} = -\dfrac{P}{4}(k - k^3) = -\dfrac{P}{4l^3}(2l^2 a - a^3)$, just as already given. The pivot span is thus but a particular case of our general formulæ.

2. *A girder of three spans, two end ones equal, has a load at a distance a from left end, what is the shear at left end?*

Let the two end spans be each $n\,l$ and middle one l. Then in this case $s = 3$, $l_1 = l_3 = n\,l$, $l_2 = l$ and $r = 1$, hence $c_1 = d_1 = 0$, $c_2 = d_2$

$= 1, c_3 = d_3 = -2(n+1), c_4 = d_4 = \frac{3+8n+3n^2}{n} = \frac{H}{n}$, if we put $H = 3+8n+3n^2$. Then $M_1 = 0$, since for $m = 1$, $c_m = c_1 = 0$. For $m = 2$ or $m > r$ we have $M_2 = d_{3l} \frac{A c_1 + B c_2}{c_2 + 2(n\,l+l)\,c_3} = -2(n+1) \frac{B}{l+2(n\,l+l)(-2n-2)} = -2(n+1) \frac{P n^2 l^2 (k-k^3)}{-l(3+8n+4n^2} = \frac{2 P n^2 l (n+1)(k-k^3)}{H}$. Now for the reaction at left end we have $S_r = S_1 = S_A = \frac{M_r - M_{r+1}}{n l} + q = \frac{M_1 - M_2}{n l} + P(1-k) = \frac{-M_2}{n l} + P(1-k)$ or $S_A = \frac{-2 P n (n+1)(k-k^3)}{H} + P(1-k) = \frac{P}{H}[H - (H - 2n - 2n^2)k + (2n + 2n^2)k^3]$ just as already given in Article 4. In the same way we might find the other reaction there given. If we make $n = 1$, we have all the spans equal, and if we should insert in place of A and B in the values for M, the proper values for uniform load, we should have the reactions for full load over any span. Making this change in the preceding examples we can compare our results with those given by *Stoney* (Theory of Strains), for the same two cases, and thus prove the accuracy of our formulæ, by a comparison of the results obtained from them, with the results of independent investigations. Such a comparison will also give an idea of the amount of labor and investigation saved by our formulæ. By the ordinary methods, the deduction of the above values would be tedious in the extreme, and would even "task the powers of the best mathematicians."

3. *In a girder of seven equal spans, we have a weight P at a distance a from the fourth support. What is the moment and shear at this support?* (The reader should in every case draw a figure.)

Here $s = 7$, $r = 4$, and since all the spans are equal $c_1 = d_1 = 0$, $c_2 = d_2 = 1$, $c_3 = d_3 = -4$, $c_4 = d_4 = 15$, $c_5 = d_5 = -56$, $c_6 = d_6 = 209$, $c_7 = d_7 = -780$, etc. Hence $M_r = M_4 = c_4 \frac{A d_5 + B d_4}{l d_6 + 4 l d_7} = 15 \frac{-56 A + 15 B}{209 l - 3120 l}$ or $M_4 = 15 \frac{-56 A + 15 B}{-2911 l}$. Inserting the values of A and B for concentrated load, we have $M_4 = \frac{15 P l}{2911}(97 k - 168 k^3 + 71 k^5)$. If in this we give to k its several values for the

various weights, P_1, P_2, etc., and insert the values of P and l, we shall find the values of M_4 for "interior loading," as already given in Article 3. In a similar manner we can find M_5, thus, $M_5 = d_4 \frac{A c_4 + B c_5}{l c_6 + 4 l c_7} = 15 \frac{15 A - 56 B}{-2911 l} = \frac{15 P l}{2911} (26 k + 45 k^2 - 71 k^3,)$ knowing now M_4 and M_5, we can find the shear $S_4 = S_r = \frac{M_4 - M_5}{l} + P(1 - k)$. If for the same girder, we suppose the first span loaded with uniform load over the whole length, and wish the moment at fourth support, we have $r = 1$ and $A = B = \frac{1}{4} w l^2$; s, c, and d the same as before, hence for $m = 4$ $M_4 = d_5 \frac{A c_1 + B c_2}{l c_6 + 4 l c_7} = -56 \frac{B}{-2911 l} = \frac{56}{2911} \frac{1}{4} w l^2 = \frac{14}{2911} w l^2$; and $M_5 = d_4 \frac{A c_1 + B c_2}{l c_6 + 4 l c_7} = \frac{15 B}{-2911 l} = -\frac{15}{2911} \frac{1}{4} w l^2 = -\frac{15}{11644} w l^2$. Now we can find the shear just to the right of fourth support, *viz.*, $S_4 = \frac{M_4 - M_5}{l}$. In like manner we can find moment and shear at fourth support for third span loaded, as also at same support for sixth span loaded. The sum of all these positive moments and shears will give us the moment and shear at fourth support for first method of "exterior loading," as given in Article 3. In the same way we can find the same quantities for second method of exterior loading. Thus our formulæ give us easily all the data, which in Article 3, we have assumed as known, and which, as we have seen, are sufficient for complete solution.

In the author's work, "Elements of Graphical Statics," will be found tables which may be easily produced to any extent by simple inspection, giving moments and shear, without even using the formulæ. Such tables are, however, scarcely desirable. The formulæ themselves are easily managed and all sufficient for our purpose.

But our formulæ enable us to solve other problems which without their aid could hardly be attempted even. By making, for instance, $l_1 = 0$ in our formulæ, the girder is *fixed horizontally* at the left end, whatever the number of spans. When $l_s = 0$, it is fixed at the right end. When l_1 and l_s are both zero, it is fixed at both ends. The girder of single span fixed horizontally at both ends is given in most text books. Let us check our formulæ by comparison with these results. Thus:

4. *A beam of one span is fixed horizontally at the ends. What are the end moments and reactions for a concentrated load distant a from left end? Also for uniform load over whole span?*

Here we take 3 equal spans, or, $s = 3$, but we make l_1 and l_3 both zero in our formulæ. The left end of the girder is then 2, the right end 3, and $r = 2$, $d_1 = c_1 = 0$, $d_2 = c_2 = 1$, $d_3 = c_3 = -2$. For the left end then we have $M_r = M_2 = c_2 \dfrac{A d_3 + B d_2}{l d_2 + 2 l d_3} = \dfrac{-2A + B}{l - 4l}$ $= \dfrac{B - 2A}{-3l}$. Now according as we insert the values for A and B, we shall have concentrated load or uniform load. Thus for concentrated load $A = P l^2 (2k - 3k^2 + k^3)$ and $B = P l^2 (k - k^3)$, hence $M_2 = P l (k - 2k^2 + k^3)$. For uniform load $A = B = \frac{1}{2} w l^2$, hence $M_2 = \frac{1}{12} w l^2$.

For the right hand support we have $m = 3$ or $m > r$, or $M_3 = d_2 \dfrac{A c_2 + B c_3}{l_2 c_2 + 2 l c_3} = \dfrac{A - 2B}{l - 4l} = \dfrac{A - 2B}{-3l}$ or $M_3 = P l (k^2 - k^3)$ for concentrated load, and $M_3 = \frac{1}{12} w l^2$ for uniform load.

For load in middle $k = \frac{1}{2}$ and $M_2 = M_3 = \frac{1}{8} P l$.

We can now find the shears S_2 and S'_3 which in this case are the same as the reactions R_2 and R_3, because there is but one span. Thus, $S_r = S_2 = \dfrac{M_2 - M_3}{l} + q = \dfrac{M_2 - M_3}{l} + P (1 - k) =$ $P (1 - 3k^2 + 2k^3)$ and $S'_{r+1} = S'_3 = \dfrac{M_3 - M_2}{l} + q' =$ $\dfrac{M_3 - M_2}{l} + P k = P (-2k^3 + 3k^2)$. For $k = \frac{1}{2}$, both these become $\frac{1}{2} P$ as should be, and all these formulæ are precisely the same as those found for this case in all text books, thus proving our general formulæ.

5. *A beam of one span is fixed horizontally at the right end only; what are the reactions and the moments for concentrated and uniform load?*

Here we have two spans, or $s = 2$, but we make $l_2 = 0$, so that $r = 1$, and $c_1 = d_1 = 0$, $c_2 = d_2 = 1$, and $c_3 = d_3 = -2$. Then $M_1 = 0$, because $c_1 = 0$, and $M_2 = d_2 \dfrac{A c_1 + B c_2}{l_1 c_1 + 2 l_1 c_2} = \dfrac{B}{2l}$ Now

inserting the values for B, we have $M_2 = \frac{Pl}{2}(k - k^3)$ or $M_2 = \frac{1}{8} w l^2$.

For the reactions or shears, which in this case are the same, we have $S_1 = S_r = \frac{M_1 - M_2}{l} + q = -\frac{M_2}{l} + P(1-k) = \frac{P}{2}(2 - 3k + k^3)$, or, $S_1 = \frac{3}{8} w l$ and $S'_{r+1} = S'_2 = \frac{M_2}{l} + Pk = \frac{P}{2}(3k - {}^3)k$, or, $S'_2 = \frac{5}{8} w l$.

For $k = \frac{1}{2}$, we have $S_1 = \frac{5}{16} P$ and $S'_2 = \frac{11}{16} P$. These formulæ and results are precisely the same as those given for this case in all text books, where they are deduced by a special discussion of considerable intricacy. It will be observed that by the aid of our general formulæ, one case is no more difficult than another, and questions may be readily solved which would be otherwise almost impossible of solution. Thus,

6. *A beam of three spans of* 25, 50, *and* 40 *feet, respectively, is fixed horizontally at the right end and has a concentrated load of* 10 *tons at* 12 *feet from the third support. What are the moments at the supports?*

Ans. $M_1 = 0$, $M_2 = -8{\cdot}20$, $M_3 = 24{\cdot}62$, $M_4 = 42{\cdot}29$. ft. tons. Find the shears, also moments and shears for uniform load over third span.

7. *A beam of four spans,* $l_1 = 80$, $l_2 = 100$, $l_3 = 50$, $l_4 = 40$ *ft., free at the ends, has a load of* 10 *tons in the second span* 40 *ft. from the left end. What are the moments?*

Ans. $M_1 = 0$, $M_2 = 82{\cdot}01$, $M_3 = 88{\cdot}56$, $M_4 = -24{\cdot}65$, $M_5 = 0$. Find the shears, also the moments and shear for uniform load over second span.

Thus we see that a few short and simple formulæ which may be written on a piece of paper the size of one hand, are all that we need for the complete solution of any case of level supports—whether the spans are all equal or all different in length, whether the girder merely rests upon the end supports or is fastened horizontally at one end or both ends. We have only to remember that a positive moment causes tension in upper flange and compression in lower; inversely for negative moment. Also, that a positive shear acts upwards and a negative shear downwards. Also, that both moment and shear are positive at

the supports of the loaded span and alternate in sign both ways from these supports. This is all we need. We can then by our formulæ find the positive moment and shear at any support for 1st case of exterior loading; negative moment and shear for 2d case; and positive moment and shear for each of the interior apex loads. We can then find the strains for each case and each weight with the same ease as for a simple girder, and in precisely the same way. Finally, by our method of tabulation given in Article 3 we can find the maximum strains, for all positions of moving load as well as for dead load, and this not approximately but with absolute exactness.

VIII. CONCLUDING REMARKS.

If we take a girder of 200 feet span, 20 feet high, 10 panels, double system of triangulation, live load 20 tons per panel, and dead load 10 tons per panel, and calculate its strains, first for single span, second, as one span of two equal continuous spans; third, as the centre span of five spans; and fourth, as fixed horizontally at the ends, we have in the second case a saving in strain of 18 per cent.; in the third, of 27 per cent., and in the fourth of 50 per cent., as compared with the first. Such results are surely indicative of considerable advantage and are worthy of serious attention!

THE DISADVANTAGES OF THE CONTINUOUS GIRDERS ARE:

1st. The fact that some of the flanges undergo strains of opposite character.

This, in wrought iron structures, we venture to think of little importance. No difficulty in this respect is found in the diagonals of the simple Warren girder. The extra work and cost of chords and chord connections necessary to secure the flanges against both compressive and tensile strains, can hardly amount to 18, 30 or even 50 per cent. of the cost of girder.

2d. Difficulty of calculation.

We have, we trust, in what precedes, succeeded in removing this objection. The opinion seems wide spread, that the determination of the strains in the continuous girder is impracticable and involved in mystery. No opinion could well be more unfounded. The accurate and complete calculation for all possible loading, live and dead, is precisely similar to, and offers no more difficulty than the simple girder itself.

3d. The changes of strain, unforeseen and often considerable, which a small settling of the piers, or change of level of the supports may occasion.

This objection is only of importance when the piers settle, *after* the erection of the superstructure. If piers are to be considered as settling indefinitely, continuous girders are indeed impracticable. If, however, the piers take in time a permanent set, and afterwards remain immovable, the above objection has no weight. It is not necessary that the piers should be on level, or even on line, or even that the difference of level be known. The proper reactions may, as suggested by Mr. Herschel, be *weighed* off, and the girder thus left in position under precisely the circumstances for which it has been calculated.

THE PRINCIPAL ADVANTAGES OF THE CONTINUOUS GIRDERS ARE:

1st. Ease of erection, where false works are difficult or expensive. The girder may be built on shore, and then pushed out over the piers.

2d. Saving in width of piers, as compared with width required for separate successive spans. The girder may be put upon *knife edges* at the piers. In fact such a construction is desirable as better ensuring the calculated strains. Width of piers is undesirable.

3d. Saving in material, ranging in general from 25 to 30 per cent.

Finally—we do not wish to be understood as claiming that the continuous girder is *in all cases* superior to the simple. It has of course its own place. Theory shows a considerable gain, and in the case of a number of long spans where the piers are solid and false works difficult, the advantages of the continuous girder seem certainly worthy of earnest consideration. The theory upon which our results are based is universally accepted as a good working theory and one whose results are practically correct. Those who seem inclined to find fault with the theory itself would do better service by giving us one more correct, rather than by dissuading others from attempting to obtain in practice the gain indicated by such theory as we have. As is seen from the above, the accuracy of our strains depends *wholly* on the accuracy with which the shears and end moments are given by the formulæ, a few *actual experiments*, made to test the practical accuracy of these formulæ would be more satisfactory and more to the point than any amount of general discussion of the theory of flexure. Such experiments can very easily be made. Those who

consult the author's work upon the "Elements of Graphical Statics" for the demonstration of the above formulæ will find that the *actual amount* of deflection, or whether this deflection can be accurately calculated, has nothing whatever to do with our formulæ. It is with relative deflection only, that we have to do. It has been our object, assuming with the great majority of engineers, the accuracy of the theory of flexure, to show an easy and practical method of calculation, which shall meet one of the main objections to the continuous girder, and to exhibit the gain indicated by theory. This we claim to have done, and in doing it we have given general formulæ, easy of application, which, we may be allowed to think, mark a new and great advance in the mathematical discussion, at least of the subject. Objections of more or less weight can always be urged against any novel construction, especially before such construction has been attempted. Just *how much* weight such objection may have, whether really insuperable or only of service in pointing out to the engineer special difficulties to be met and overcome by special skill, can only be determined by ACTUAL TRIAL. No man without such actual experience can authoritatively state just how much or how little of the theoretical gain can be attained in practice, though there are not wanting those who assume to be equal to the task. The only fair and legitimate way of testing theoretical results seems to be by actual trial. Such at least seems to be the view held abroad. In almost every civilized nation, *except America*, the continuous girder has been or will be put to a practical test, and it is hard to see why it should not be tested here. Those who decide the case *prima facie*, and, in the light of what is doing abroad, dissuade even from experiments, would seem to place rather too much confidence in their own judgment and too little in the skill and enterprise of their compeers in other countries, while their claims as *progressive* engineers are liable to be questioned.

Errata.—In article on Gas Works Engineering, page 35, vol. CII, correct line 22, for two, read ten; line 25, for When a, read Whence. —The computation of the number of feet of air needed for a burner of $4\frac{1}{2}$ cubic feet per hour = 90 cubic feet, is correct.

DAVEY'S DIFFERENTIAL VALVE GEARING.

Abstracted from Thesis of

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One of the greatest defects of the direct pumping steam engine—that is, the pumping engine which is constructed without a crank, and fly-wheel, and a rotary movement, to limit the length of stroke—is its liability to overrun the proper stroke of the piston, to the serious injury of the head, or of the cylinder, or in fact of the whole machine.

In these engines the initiatory motion is imparted to the valve gearing by some tappit or release of catch, as the piston approaches either end of the stroke, while with the intervention of some one of many contrivances, the actual opening of steam ports is deferred until after the whole, or nearly the whole length of the previous stroke of the pump will have been completed. In some way, at the proper time, the valve gearing opens the ports to the steam cylinder, and at some proper and fixed point in the stroke these ports are closed against further admission of steam by another tappit, release-catch, or in some cases a gradual inclined plane movement; so as to allow a maximum of expansion in bringing the piston to rest at the full end of the stroke without shock. With a constancy of load and of steam pressure, this arrangement works satisfactorily, but with the variation of either, and especially of the former—which is most liable to sudden variations, accidental or otherwise—stoppages or overrunning are likely to occur. In the case of the bursting of a main delivery pipe, for instance, the full force of the expansion of the steam which may have (and for a non-compound cylinder steam pump, must have), followed the piston, seven-eighths of the stroke, will be expended in bursting out the cylinder head.

The Cornish engine itself is included in the same category as to danger of overrunning its stroke at either end, in event of disturbance of its motive pressure or working load. In this engine, the steam imparts to an immense mass, a certain momentum in the beginning of the stroke, and aids in the continuance of the motion of the mass until the very end of the stroke is reached, when the elevated mass

comes to rest. The mass on its return descent, imparts to a column of water its proper movement under nearly uniform resistance. Now if accidentally, either the connection between the engine and the ascending mass, or load is broken; or any material change occurs in the water column resistance, the probability of disaster is very great. Cornish engines require constant attendance to guard against such accidents, but the utmost care fails to prevent these at times. Many of the Cornish engines in this country have suffered injury in this way, of greater or less amount. The instance of a failure at Jersey City two or three years since, may be quoted, where the ensuing expenditures for repairs reached the sum of $25,000.

Within the past two or three years Mr. Henry Davey, of Leeds, England, has introduced a differential (as he denominates it) valve gearing, whereby the valve movement is made to depend upon an independent cataract on the one hand and upon the relative speed of the piston itself on the other.

The cataract, here referred to, is a cylinder with its piston; which cylinder is full of water on both sides of the piston, and the piston in the course of its movement is made to displace the water from one end to the other end of the cylinder—from one side to the other side of the piston—through a *restricted* side pipe or passage. The motion is imparted to the piston of the cataract by an independent steam cylinder (*J*) *whose valve motion* is derived from a tappit which operates near the end of the stroke of the main steam cylinder; and the *time* and *uniform resistance* of the cataract follows from the restriction of the side pipe by a screw valve or an equivalent means for controlling the flow of water in the water cylinder. Having thus secured a motion of desired uniformity of rate to be accomplished as a *stroke* in a desired interval of time—say any number of strokes (3 to 60 as wished) per minute—this motion is applied, under Mr. Davey's invention, to operate *indirectly* the steam valve of the engine. This indirect operation is produced by *connecting* the piston rod of the cataract to one end of a balance bar, while the other end of the balance bar is *connected* in the opposite direction to the piston rod of the main engine. The *connection* in the latter case being so planned by rocker arms or inclined slides, that the length of the stroke to that end of the balance bar is in reasonable proportion, or equal to that of the cataract. When it results, that if the main valve rod is joined to the balance bar at some place in its length, the action of the cataract tending to open

the main valve, will be counteracted by that of the engine tending to close it, and the valve will have the "differential" motion.

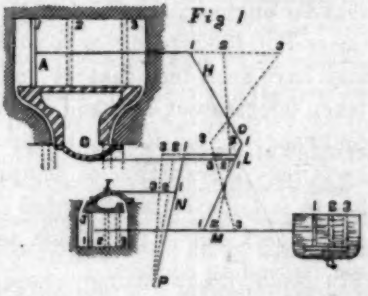
Suppose the engine to have come to rest at one end of the stroke, and suppose a slide valve to be used as the means for admission; of course the valve in such case will have a middle position, and cover the ports of admission at both ends. Just before the engine reached this position of rest, a tappit is supposed to have admitted steam to the cataract steam cylinder, and presently that end of the balance bar begins to move, whilst, as the engine is at rest, the other end of the balance bar is at rest also; and under these circumstances, the point of attachment of the main valve rod to the balance bar is put in motion, and the valve begins to open. The main valve continues to open in this way until the pressure of steam admitted to the cylinder overcomes the resistance of the column of water, when a slow movement commences. The cataract continues on its uniform speed, but as the previous fulcrum end of the balance bar is now in motion, the main valve now opens more slowly. Presently the rate of motion of the two ends becomes coincident, or has such relative speed, that the point of attachment of the main valve rod ceases, when the valve opens no further; or else the cataract, reaching its limit of motion, and will have produced its utmost effect on the valve, when it follows that the engine connection to the balance bar will close up the valve at the end of the stroke; or, on the other hand, the speed of the engine may have been such that its end of the balance bar will have overtaken the cataract end, and shut off the valve faster than the cataract could open it; or, finally, the speed of the engine, in case of a runaway by failure of resistance to pumping, may cause its end of the balance bar to so far overrun the speed of the cataract end as to admit steam on the back side of the piston, and present a steam resistance against the impending contact.

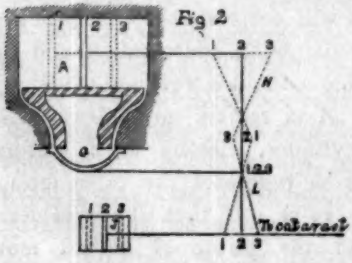
In Mr. Kilham's thesis the following figures are employed to illustrate this action, and his description will complete the elucidation of the apparatus, which is provokingly simple in construction and exceedingly difficult to render intelligible without a working model.

"Suppose, in Fig. 1, the piston A to remain motionless; then the piston J of the subsidiary cylinder, moving at a uniform speed, would move the point L which regulates the valve motion toward the right, thus opening the valve. If then the subsidiary piston J should remain still, and the piston A should move

forward, the point L would move toward the left, thus closing the valve; so that if the motions occurred successively, the first would open and the second close the valve, and close it always at the same fraction of the engines stroke, whatever the boiler pressure and load. But if these motions act together we obtain a differential motion compounded of the two. First the steam is admitted to the subsidiary cylinder, and the piston J by its motion moves the rod L and, since steam has not yet been admitted to the main cylinder, L turns about O as a fulcrum, thus opening the valve G. As soon as steam is admitted A begins its motion, slowly at first but more quickly as the inertia of the load is overcome. When A starts there are two tendencies; first that of J to open the valve, and second that of A to close it. At first the motion of L derived from J is the greater, and the valve continues to open, but as the speed of A increases, the motion of L derived from it becomes equal to that derived from J, and the valve motion ceases. As the speed of A still increases the valve begins to close. When the valve is closed, as the steam is working by expansion only, the speed derived from J again becomes equal to that derived from A, the valve again stops at the other end of its throw, and the engine is ready for the return stroke."

"In Fig. 1. are shown the positions of the different parts of the gear at the beginning and end of the stroke, and at the point of cut-off. In Fig.2, suppose the positions marked 2 to be the positions occupied by the different parts shown in the figure at the point of cut-off, working under the ordinary load. If the load were heavier, the





steam pressure being the same, it would take longer for the motion of the valve, caused by the main piston, to equalize that caused by the subsidiary piston, and it would therefore be longer before the direction of motion of the valve would be changed, and longer before cut-off would take place than with the ordi-

nary load. If on the other hand the opposite should occur, the cut-off would take place earlier in the stroke. The positions marked 3 and 1 are those occupied with a heavier or lighter load."

"If from any cause the load was suddenly thrown off the increasing speed of the piston would be immediately felt by the valve, which would thus be changed to compensate for the loss of load. First suppose that the load is thrown off before cut-off occurs, then the increasing speed of the main piston quickens the cut-off. Second, suppose the load continues as ordinarily until just after steam is cut off, and then the load is thrown off—the subsidiary piston *J* will move on uniformly, unaffected by the load, while the main piston, having little resistance, moves with great velocity, so that the subsidiary piston moves a very short distance compared with the main piston. Actuated by the main piston principally, the valve moves quickly and opens before the valve reaches the end of its stroke. The positions at point of cut off and near the end of the stroke are seen in Fig. 3. By the admission of steam the piston is stopped, and would begin to move the other way, but since both its motion and that of the subsidiary piston tend now to close the valve, no more steam will be admitted until the subsidiary piston reaches the position ordinarily occupied at admission."

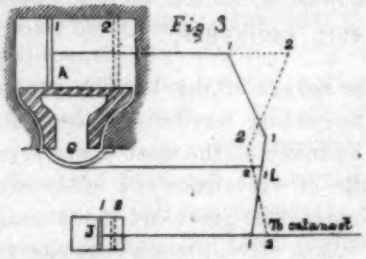


Fig 3

The description and sketches given above, do not exhibit the constructive details and mechanism of Mr. Davey in actual use. A paper read by him before the Institution of Mechanical Engineers in 1874, shows many examples, both of proposed and accomplished application. This paper, with further additions, has been subsequently republished in various engineering journals. It has been here attempted, to present as clearly as possible, the principle of controlling movement involved in Mr. Davey's plan, divesting the mind of the reader from the embarrassment of consideration of methods of construction. The refinements for adjusting tappits, whereby the cataract steam (or motive) cylinder is operated, and the control or regulation of their action, have been fully comprehended and met by Mr. Davey, as will be found by any person, who shall pursue the inquiry into

his published articles. The valve gearing itself is an adaptation of what has been applied to meet similar requirements in mechanical combinations repeatedly, so that no part can be called novel or entirely original. Perhaps the nearest approach to the same application is that used in the movement of valves for the Davy (Davy of Sheffield, not Davey of Leeds), steam hammer, which has now met with nearly universal acceptance for the hand and power valve movement for steam hammers. But the combination of the governing cataract with the balance bar, for operating the valves of steam pumping engines is (the writer thinks) new, and is probably the most important modification of this valve gearing effected since the time of Smeaton, that is, within the last century of the history of pumping engines.

VENTILATION.

An abstract from a paper by Gabriel James Morrison, M. Inst. C.E., was read before the INSTITUTION OF CIVIL ENGINEERS,

London, January 18th, 1876, on the subject of the Ventilation and Working of Railway Tunnels. The reading was followed by a discussion which was participated in by many of the most eminent engineers of England, and the results of experience and study were elicited in exceedingly instructive forms. The great end of the paper and discussion was to consider the means of ventilation requisite for the proposed "Channel tunnel" of 22 miles in length; and those readers, who wish to investigate or understand the methods for effecting the purpose suggested or advocated by the different engineers, are referred to the proceedings of the Institution for the complete report. But there were several data given in the paper, and by different speakers, which possess more general interest, which can be appropriately abstracted in the JOURNAL.

For instance, Mr. Morrison gives a succinct statement as to FRESH AIR, ITS COMPOSITION AND PROPERTIES, which can be quoted.

"Pure air consists, approximately, of 23 per cent. of oxygen and 77 per cent. of nitrogen, weight for weight—or 21 per cent. of oxygen and 79 per cent. of nitrogen, comparative volumes:—but in addition, the atmosphere always contains carbonic acid, so constantly, that it is questioned whether this gas be not a necessary constituent. The quantity is very small, for Dr. Angus Smith states that on the

hills in Scotland the proportion was found to be 3·8 per 10,000; in the open parts of London 3 per 10,000, and in London streets 3·8 per 10,000.* In this paper fresh air will be considered to contain $3\frac{1}{2}$ parts of carbonic acid in 10,000 parts; and the temperature of 60° Fahr. will be generally adopted, at which temperature the weight of a cubic foot of air is 0·0765 lb.

The specific gravity of air being . . .	1
That of oxygen is	1·1
" nitrogen	0·97
" carbonic acid	1·52

"Carbonic acid consists of 6 parts by weight of carbon and 16 parts by weight of oxygen: the volume of the Carbonic acid is the same as that of the sixteen parts of oxygen. This gas is therefore $\frac{6}{16}$ heavier than oxygen."

In another place in his paper Mr. Morrison gives the following empirical formulæ for the FLOW OF AIR THROUGH DUCTS OR PASSAGES.

"The friction of air varies as the square of the velocity multiplied by the pressure against the sides of the passage. This pressure being uniform, its total amount depends upon the total surface, that is, the length multiplied by the perimeter of the cross section. The force required to propel air through any passage is therefore equal to the square of the velocity into the total surface multiplied by the co-efficient of friction. It is more convenient to state the force in lbs. per square inch or per square foot, or as so many inches of water pressure; the above result should therefore be divided by the area of the cross section.

The best form of the formula for practical purposes of ventilation seems to be: $H = \frac{KV^2PL}{A}$, where

H = head of pressure in feet of air of same density as the flowing air.

L = length of the pipe or passage in feet.

P = perimeter of cross section in feet.

A = area of pipe or passage in square feet.

V = velocity in thousands of feet per minute.

K = co-efficient of friction = 0·03.

This formula is perfectly general, and may be used for any fluid; H will always be the head stated in feet of the flowing fluid.

* "Air and Rain." By Robert Angus Smith. 8vo., London, 1872.

The weight of 1 foot of air, at 60° Fahr., is 0·0765 lb. per square foot. The weight of 1 inch of water is 5·2 lbs. per square foot. Therefore if it be desired to reduce any result in feet of air to its equivalent in inches of water, the process is simply to divide it by $\frac{5{\cdot}2}{0{\cdot}0765} = 68$.

For circular passages, taking D for the diameter, the formula becomes $H = K\,V^2 \times \frac{4\,L}{D}$.

These formulæ are only applicable to passages whose diameter is small in proportion to their length. For short passages the length should be increased by about 50 diameters of the passage: thus the formula for circular passages becomes $H = K\,V^2 \times \frac{4\,(L+50\,D)}{D}$, and that for irregular-shaped passages, $H = K\,V^2 \times \frac{P\,L+200\,A}{A}$.

The value 0·03 is deduced from a formula explained by Mr. Hawksley, Past-President, in a discussion on the ventilation of Coal Mines.*

In a paper on the Ventilation of Coal Mines, read before the Geological Society of Manchester in 1862, Mr. Atkinson adopts the same formula as the author, but gives a constant of 0·26881, or nearly ten times that of most authorities.† Mr. Atkinson gives a table of co-efficients depending on the material of which the passage is composed:—

Material.	Observer.	Co-efficient.
Burnt earth . . .	Peclet	0·268
Galleries of coal mines .	Greenwell	0·254
Sheet iron (clean) . .	Peclet	0·067 to 0·105
Cast iron (old and tarred)	Giraud	0·048
Gas in pipes . . .	Hawksley	0·030
Water in pipes . .	Eytelwein	0·030
Sheet iron (old and rusty)	Girard	0·027
Tinned iron . . .	D'Aubuisson	0·025

In a discussion on Fans, Mr. Greenwell stated that the co-efficient of friction varied according to the nature of the sides of the passage,

* *Vide* Minutes of proceedings Inst. C. E., vol. vi, p. 192.

† Quoted also, by C. Cope Pearce, in the transactions of the South Wales Institute of Mining Engineers, vol. v. The figures, however, are taken from the original.

as shown by Girard, D'Aubuisson, &c.* To this Mr. Hawksley replied that these discrepancies arose from badly conducted experiments; he had had good opportunities of making experiments in mines with long uniform airways, as well in pipes, and there were not in reality any such differences of co-efficients. On another occasion† Mr. Hawksley said that, when the density of any elastic fluid did not materially vary throughout the length of the pipe, the same rule as for inelastic fluids applied, and that the general formula was $V = 48\sqrt{\frac{h\,d}{l}}$. V being the velocity in feet per second; this formula, reduced to the form adopted by the author, gives a constant of 0·031. From Eytelwein's formula according to Beardmore the author deduces 0·028 as the constant. In a paper by Mr. Lowe, the constant is given as 0·030, and in an old formula, possessed by the author for many years, the constant is given as 0·028. From experiments on the pneumatic tube from Euston to Holborn,‡ taking the velocity of the air to be that of the carriage, allowing nothing for the work done in moving the carriage, a maximum value is obtained of 0·036, and making allowance for the weight of the carriage, the results give a probable value for the constant of 0·027. The experiments in Lime Street tunnel (at Liverpool), are not well suited for deducing a constant,‖ the length, 1,200 yards, being hardly as great in proportion to width as is desirable. From the data given, making use of the formula for short passages, the constant comes out 0·049; but the velocity of the air may have been higher than taken: a difference of 20 per cent. would bring the constant to the same figure as the others. From experiments made at Crewe, shortly before the ventilation of this tunnel was carried out, the following formula was deduced:— Discharge in cubic feet per hour, $1{,}314\sqrt{\frac{d^5\,h}{l}}$; d = diameter of pipe in inches, h = head in inches of water, l = length in yards. This gives a constant for the formula adopted by the author, of 0·029. The author believes that the authorities quoted are sufficient to justify him in adopting 0·03 as the value of the constant K.

* *Vide* Minutes of proceedings Inst. C. E., vol. xxx, p. 304.

† *Ibid.*, vol. xxxiii, p. 53.

‡ "Engineering," 23d Aug., 1872.

‖ *Vide* Inst. Mech. Eng., proceedings, 1871, p. 22 *et seq.*

It will be convenient now to consider the best position for applying the power, so as to insure the supply of a proper amount of fresh air.

The most obvious arrangement is to withdraw the air from the centre of the tunnel. Where this method is applicable no other can compete with it; no valves or doors are required; the air enters at both ends of the tunnel; and the speed of current necessary for ventilation is therefore only half what it would be if the current entered at one end and passed out at the other.

This system has been adopted at Lime Street tunnel, Liverpool. The tunnel is 2,025 yards long, and the air in it is entirely changed in eight minutes; 431,000 cubic feet are withdrawn per minute, and the resistance of the tunnel is so slight that a partial vacuum of 0·14 inch of water is sufficient to cause this; indeed almost the whole of the power appears to be expended in overcoming the friction of the air in the shaft. The case is somewhat peculiar. There is a considerable incline, and therefore the heavy (that is to say, the coal-burning) traffic is in one direction only. The fan is placed in a shaft 1,212 yards from the lower end of the tunnel. As soon as a train is ready to start, the fan is set in motion. The train takes three minutes to run through; the lower portion of the tunnel is entirely cleared in five minutes, and the upper portion in four and a half minutes from the time the train reaches the top of the tunnel. The fan is only worked when required: when not at work the tunnel clears itself by natural ventilation in forty-five minutes. In the case of short tunnels, with frequent trains, or of long tunnels with a smaller number of trains, this intermittent system would be inapplicable.

A tunnel half a mile long, with thirty trains per hour, would represent the worst cases on the Metropolitan railway. If artificial ventilation were adopted, all the products of combustion must enter the tunnel. At a shaft near the centre of the tunnel, all the air might be drawn from the stations, which would then be constantly full of fresh air, and the passengers on the platforms would never feel any discomfort. Supposing, as in the second example given above, a consumption of 24 lbs. of carbon per train mile, to bring the amount of carbonic acid down to the proportion of 8½ parts per 10,000, the tunnel must be filled three times for every five trains, or eighteen times per hour; as the tunnel is a half mile long, and is filled from both ends, the velocity of the current will be nearly 400 feet per

minute, and there must be withdrawn $473 \times 400 \times 2 = 378{,}400$ cubic feet per minute. This is less than the duty of the fan at the Lime Street tunnel.

The head of pressure is: $H = K\,V^2 \times \frac{PL + 200\,A}{A} = 0{\cdot}03 \times 0{\cdot}4^2 \times \frac{83 \times 1{,}320 + 200 \times 473}{473} = 2{\cdot}07$ feet of air $= 0{\cdot}03$ inch of water.

As probably a head of $\frac{3}{4}$ inch of water, or 3·9 lbs. per square foot, will be required to force the air through the passages leading from the tunnel, the friction of the tunnel proper is not worth considering. Air to the amount of 380,000 cubic feet per minute withdrawn against a vacuum of $\frac{3}{4}$ inch of water represents an effective *HP* of

$$\frac{380{,}000 \times 3{\cdot}9}{33{,}000} = 45.$$

At such low pressures, the effective power of a fan can scarcely exceed 50 per cent. of the indicated *HP* of the engine, so that about 90 *HP* will be required.

A tunnel 7 miles long, with sixteen trains per day, consuming on the average 35 lbs. of carbon per mile, would have to be filled once for each train, or sixteen times in twenty-four hours. This would require a current from one end to the other of 410 feet per minute; for, in the case of very long tunnels, it rarely happens that it is possible to have a shaft in the middle. In the Hoosac Tunnel there is such a shaft, and of course if that tunnel were to be ventilated artificially, advantage would be taken of it; but, as a rule, long tunnels are constructed to overcome great natural obstacles, and are without a shaft from end to end.

Assuming the same size of tunnel as before, and taking the formula for long passages, $H = \frac{K\,V^2\,P\,L}{A} = \frac{0{\cdot}03 \times 0{\cdot}41^2 \times 83 \times 36{,}960}{473}$, $= 33$ feet of air $= \frac{1}{2}$ inch of water. If $\frac{3}{4}$ inch be allowed for the friction in the air channels, it will give $1\frac{1}{4}$ inch pressure altogether. The necessary pressure in mines is often considerably higher; but even in what are considered properly ventilated mines, the air-passages are often so small that a man can scarcely crawl through them. If the number of trains be twelve per day, the average current to ventilate the tunnel will only be $3\frac{1}{2}$ miles per hour; and if a proportion of $13\frac{1}{2}$ parts of carbonic acid per 10,000 be permitted, it will only be $1\frac{1}{4}$ mile per hour."

Doct. Letheby (since deceased) gives some very valuable statements on "THE QUANTITY OF CARBONIC ACID EVOLVED IN RESPIRATION, ETC."

"Experiments dating from the time of Sir Humphry Davy had established beyond question the precise quantity of carbonic acid produced by each individual when at rest. Each person consumed about 2¼ grains of carbon per minute, equal to 8·25 grains, or rather more than 17 cubic inches, of carbonic acid, and, with the hydrogen consumed in his body, it amounted to about 20 cubic inches of atmospheric oxygen consumed in a minute. Dividing the 7,000 grains making a pound of the combustible, by 4½ grains, the amount consumed by each person in the run of 1 mile at the speed of 30 miles an hour, it would be seen that there were one thousand five hundred and fifty persons to every pound of carbon. That was an important consideration in regard to the extent to which each individual vitiated the atmosphere, for it showed that the vitiating effect of respiration was insignificant. With reference to other vitiating agents, carbonic oxide was one of the most deadly. One per cent. of it in the atmosphere of a tunnel would kill every person in it in ten minutes: hence the great importance of a perfect combustion of carbon. As to carbonic acid, the proportion found in the breath was about 4½ per cent., but this was irrespirable; even 2 per cent. of carbonic acid in the atmosphere was exceedingly distressing. In some dormitories examined by Dr. Bence Jones, where the "casuals" were in a very uncomfortable state, the percentage of carbonic acid was only 1¼. In others in England and France, where there were from 58 to 80 volumes of carbonic acid in 100,000 of air, the inmates did not appear to suffer much; and the same was the case with some of the crowded lodging-houses of the city, where he had found as much as 100 volumes in 10,000 of air: so also in certain mills and workshops with from 28 to 30 volumes of carbonic acid in 10,000 of air. The atmosphere of the Court of Chancery had contained 19·8 volumes of carbonic acid in 10,000; that of the Chamber of Deputies in Paris, 25 in 10,000; the London theatres, 10·2 in 10,000; and those of Paris from 23 to 43 per 10,000. He thought therefore that the maximum of carbonic acid of 15 volumes to 10,000 volumes of air could be endured for a time in a tunnel. Not that he would recommend any one to live constantly in such an atmosphere, but he did not know that it would do any harm for a reasonable time. He

looked upon 10 in 10,000 as the point where the atmosphere was getting bad; but there were many instances in which persons lived, apparently without discomfort, in an atmosphere containing considerably more than 15 volumes of carbonic acid in 10,000 of air. There was, he thought, no great cause for alarm with regard to the future of tunnels: for supposing that a normal atmosphere contained 4 volumes of carbonic acid in 10,000 of air, and that 15 volumes of carbonic acid might be permitted to exist in it, then if 35 lbs. of pure carbon were consumed per mile in a tunnel there would be produced 1,097 cubic feet of carbonic acid gas, which, with the oxygen consumed, would require only 1,002,757 cubic feet; amounting, with a sectional area of 473 square feet, to 2,120 feet of tunnel, or about $\frac{4}{10}$ mile. So that supposing the tunnel to be impervious, not allowing the diffusion of gases through the walls, if it were ventilated once for every two trains, that would be a good and effective ventilation. But suppose the ventilation could not be effected, the question will then arise whether some other fuel, less vitiating in its action, could not be used. Twenty-seven pounds of benzole, doing the work of 35 lbs. of pure carbon, or of 37·9 lbs. of coke containing 92·4 per cent. of carbon, would consume 980 cubic feet of oxygen, and produce 786 feet of carbonic acid, and it would vitiate only 719,445 feet of air; 27·7 lbs. of the common oils, doing the same work, would consume 1,072 cubic feet of oxygen, and produce 673 cubic feet of carbonic acid, vitiating 617,178 cubic feet of air. The fuel that vitiated the atmosphere to the least extent was wood spirit; but it was unfortunate that, in descending in the scale of vitiation, compounds were reached that were richer and richer in hydrogen, and therefore more and more volatile, though they might be used in the form of spray from a jet. In the case of paraffine oil, it took 23 lbs. to do the work of 25 lbs. of pure carbon, the oil consuming only 932 cubic feet of oxygen, producing 621 cubic feet of carbonic acid, and vitiating 569,202 cubic feet of air. But was it possible, by any contrivance, to use hydrogen? No carbonic acid would then be generated; there would simply be an abstraction of oxygen. He had made experiments on birds, to ascertain how far he could go in the absorption of the oxygen of the atmosphere, taking care to remove the carbonic acid as fast as it was produced; and he found that he could bring down the proportion of oxygen to less than one-half without the bird showing any sign of distress. Now 11·6 lbs. of hydrogen would do the work of 35 lbs. of pure carbon. It amounted

to nearly 2,190 cubic feet; and if that could be carried, it would consume only 1,095 cubic feet of oxygen, producing no carbonic acid, and it would only destroy 5,460 cubic feet of air. The hydrogen might be so used that the whole theoretical quantity of heat (twice as much as the practical quantity) might be utilized; and, considering how much was lost by the carbon, he was not sure whether 5½ lbs. of hydrogen, instead of over 11 lbs., would not do the work of the 35 lbs. of carbon. Then another question arose, whether, if the fuel could not be altered, anything could be used to absorb the carbonic acid as fast as it was produced? Twenty-eight pounds of lime would absorb 22 lbs of carbonic acid, the product of 6 lbs. of carbon. He did not think there would be much practical difficulty in the use of lime in a tunnel, if, instead of the engine discharging the steam and the products of combustion together, the products of combustion were made to pass through lime purifiers; and in that way the whole of the carbonic acid would be absorbed.

Mr. Tomlinson (whose previous popular publication has made him an authority in ventilation) describes the first results of the efforts, made under his direction, in ventilating the tunnels of the Metropolitan railway. Frequent shafts already existed along the lines of tunnels of this railway, which had been constructed with a view to give outlet or escape to the foul air, previous to a last attempt to relieve the difficulty, and these shafts have been made effective by the interposition of some deflecting screens, placed within the tunnel, across the headroom, above the top of the trains. By means of these deflectors the current of air which flows with any passing train is intercepted, and directed by the form of the screen surface upward and outward, through half of the shaft opening, which is bratticed or partitioned off for the efflux of the foul air; while the vacuity of air, which is created on the opposite side of the screen, after the train had passed, is supplied by fresh air, which is sucked down the other half of the divided shaft, (the inner side of the screen having the proper shape to induce the entering air to follow the train with the least resistance).

For tunnels where one or more shafts are practicable, this method of Mr. Tomlinson appears, with the possibility of many modifications, to present a ready and economic way of obtaining the desired relief. An investigation of the nature of the current of air accompanying a train, either in open air or enclosed in long or short ducts, at different rates of speed, might form a proper sequel to these "proceedings"

of the Institute. Such an enquiry would probably demonstrate, that, at some given length, rate of speed, and number of trains, a short double or single track tunnel of given cross sections would be practically self ventilating; and that the length of a single track tunnel which should not demand or make desirable some other means of ventilation would far exceed that of a double track; so that at some point a double tunnel should be preferred to a single one for a double track line, etc., etc.

It is apparent that this method of Mr. Tomlinson is not applicable to tunnels of great length, where frequent shafts, as compared to the traffic, are not admissible, as for instance the Mt. St. Gothard, Mt. Cenis, or the Channel tunnel; and that further and more complete information in accordance with the suggestion of Doct. Pole, as to the condition of ventilation at the Mt. Cenis tunnel at this time would be highly acceptable.

Chemistry, Physics, Technology, etc.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS DURING THE LAST TEN YEARS.*

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. cii, page 57.]

A few singular proposals for effecting a reduction of temperature may be finally mentioned. J. B. Toselli, of Paris,† causes a spiral pipe to revolve in a vessel of water, from which it simultaneously, during each rotation, raises a certain quantity of water and transfers it to an adjacent vessel, whence it flows back through a worm into the former. The spiral, during its revolutions, has its entire surface moistened. A ventilator drives air against it, evaporates the adhering layer of moisture, and thus lowers the temperature of the tube and of the water it contains. A refrigeration of from 2·7° to 18·3° C. is

* "Berichte über die Entwickelung der Chemischen Industrie Während des Letzten Jahrzehends."

† Toselli, *Mech. Mag.*, 1872, 433. *Dingl. Pol. Journ.*, ccv, 28.

said to be thus produced according to the weather. In the second vessel, which is traversed by a worm containing the cold water, is placed the liquid to be cooled, such as worts of beer, artificial mineral waters, &c. The effect produced can be but trifling, and depends entirely on the state of the weather, and on the amount of atmospheric moisture, which is never wanting. A psychrometer fixed in the place where the experiment is to be made will show the result beforehand with tolerable accuracy.

Ballo,* of Pest, produces cold by forcing very finely divided air through bisulphide of carbon. The condensation of the liquid needful for its recovery is a hindrance, on which, in fact, the entire project must be wrecked. A recovery of the bisulphide of carbon by any other means than by condensation and refrigeration of the air saturated therewith is, in the absence of suitable solvents, impossible. Even by this means it would involve much difficulty and a great expenditure of force, and would bring us back to the principle of the air machine. In this direction the problem is practically incapable of solution.

Preservation of Ice.

As a supplement to our report on the principles of the artificial production of ice, and on the apparatus hitherto devised for this purpose, a few words must be added on the arrangements for the preservation of cold in the concentrated form of ice. This is a question of great practical importance. Ice machines, however they may be eventually improved and their effect increased, will never, in the more northern parts of the temperate zone, where a moderately cold winter with frost is generally experienced, acquire importance enough to meet the demand even approximately. They will serve merely as valuable substitutes to render us independent of the fickleness of the seasons. Even in more southern regions where ice machines are the only source for obtaining ice, they must work to stock and fill magazines, since the demand does not go hand in hand with the production, but varies with the weather. There is in general no conception of the quantities of ice which certain trades require, and which are consumed in domestic life where its use has grown into a necessity. In 1866 the quantity of ice consumed in New York and its vicinity amounted to 250,000 tons (254,015 metric tons) or 5 cwts.

* Ballo, *Dingl. Pol. Journ.*, ccxi, 345.

per head. The weight stored up was 543,000 tons (551,721 metric tons), whilst the capital employed in the trade amounted to 2,160,000 dollars. The retail price was for quantities of 5 to 12 kilos. 4 pfennige* per kilo., but for quantities of 1 to 10 cwts. only one shilling per cwt.

In 1871 a company in Berlin, the "North German Ice Works," stored up 600,000 cwts. of ice, and delivered it to subscribers at 77 pfennige per cwt. The quantities of ice consumed in brewing may be learned from the following data, which the author obtained in 1869 from Dreher's brewery at Klein Schwechat, near Vienna:— This establishment brewed, in 1867, 483,150 Viennese eimers, = 273,463 hectolitres, and stored up 515,600 cwts. (28,874,219 kilos.) of ice. In the following year these numbers rose to 492,499 eimers (278,754 hectolitres) of beer and 563,058 cwts. (31,531,924 kilos.) of ice. On an average 1 cwt. of ice is used per eimer (56·6 litres). In a prolonged frost of 2 months this quantity can be procured at the cost of 7 Austrian kreutzers (14 pfennige) per cwt. In shorter periods of cold the price rises to from 10 to 12 kreutzers, to which must be added 1 kreutzer for shoveling into the ice cellars. In mild winters the ice is brought in part from Styria; as the cold weather in 1869 set in late, 26,000 cwts. (1,456,031 kilos.) were procured from there, costing, by the time it reached the brewery, 115 florins per 200 cwts.

In breweries ice is still universally stored in walled pits, which are placed near the store cellars, and keep the latter cool. In Dreher's establishment the cellars occupy 113 cubic fathoms = 771·05 cubic metres, serving to store 3600 to 3800 eimer of beer = 2038 to 2151 hectolitres, and the adjoining ice pit contains 65 cubic fathoms (413·52 cubic metres) holding about 6510 cwts. (368·466 kilos.). The ice pits have the defect of being costly in construction and uncertain in their action. If ground water flows in over the floor, the ice melts rapidly. Where ice is stored up for sale in large quantities it is better to construct ice houses above ground, after the American plan, consisting essentially of double walls of wood with an interval of at least 0·3 filled with some bad conductor of heat, such as sawdust, chaff, loose peat, &c., in a dry state. Thus, the North German Ice Works at Berlin had, in 1871, an ice house 180 metres long, 24 wide,

* The German "pfennig" is about the tenth part of an English penny.

and 10 high, for the storage of 600,000 cwts. of ice. Such ice houses are cheaper than the subterranean ice pits, more convenient in use, and preserve the ice better, if only the layer of non-conducting matter is thick enough. The author* has treated this subject at length elsewhere. Every season new methods of preserving ice are announced in the papers. None of these are at all novel in principle; they depend upon causing a heap of ice to freeze together, if possible, and then covering it with a bad conductor of heat, such as straw, moss, &c. This is in the south of Germany but an unsatisfactory method; far in the north, especially in Russia, it may succeed. Such coverings, further, are very perishable. A cheap and effective ice house on a small scale can only be made in our latitude by preparing two cubic boxes, the inner measuring not less than 2 metres with an interval of at least ½ metre between it and the exterior box in every direction. This interval is not left void, but filled with chaff, chopped straw, dry spent tanner's bark. The only entrance is a door of the same thickness as the sides. According to calculation in a well-made ice house of this construction the ice scarcely melts in a year at the distance of 15 centimetres from the walls. To divide the interval between the double sides into several compartments alternately filled with a bad conductor and left empty—as occasionally recommended—is decidely irrational, being more costly and less effective than a single well-filled broad interval. The air, though the worst conductor of heat, yet if it can move freely in a given space, rapidly transfers heat from a warmer to a colder surface. It is sometimes recommended, and even attempted, to improve a bad ice house by throwing a quantity of salt upon the ice. The author has shown† that this is a very irrational procedure, since, although the cold may be increased to the senses, a considerable loss of ice ensues, the access of heat to the ice pit being accelerated by the augmented difference in temperature.

The preservation of ice is not only important on the large scale, but it is of consequence on the small scale in domestic operations. Food is to be kept cold and thus preserved from decay, or ice is to be used directly for cooling purposes. For this purpose closed boxes are employed under the name of ice cupboards or ice chests. The theory of these contrivances has been examined by the author‡. The ice

* *Baden. Gewerbzeitung.*, 1870,71, iv, Nos. 5 and 6.

† *Baden. Gewerbzeitung.*, 1868,74.

‡ *Baden. Gewerbzeitung.*, 1868, 66, and 1869, 11 and 16.

closets are cupboards with double sides, the interval filled with chaff, &c., and the insides carefully lined with sheet zinc. The interval between the sides is often too small. According to the author's experiments, the entire breadth of the double side should not be less than 10 centimetres if the ice is to be preserved from rapid melting and a temperature of say 4° C. is to be maintained within. It is also preferable to place the ice in the entire upper third of the closet so that the lower two-thirds remain at liberty for food, &c. The entire cover is then made to open. The ice can then be easily taken out in pieces, and the whole lower space is equally cold, whilst if the ice is placed in a lateral compartment, as soon as it melts only the lowest part of the closet is thoroughly cooled.

Chlorine, Bromine, Iodine, and Fluorine.

By Dr. E. MYLIUS, of Ludwigshafen.

The application of the three closely allied halogens, chlorine, bro mine, and iodine in the chemical arts depends entirely on the energy with which they combine with electro-positive elements, more especially with hydrogen. In this respect chlorine enjoys the pre-eminence. Its most extensive application in the free state is, therefore, as a bleaching and disinfecting agent. Its efficacy depends here essentially on its remarkable affinity for hydrogen, which, under certain circumstances, even exceeds that of oxygen. Its more energetic affinities, in comparison with bromine and iodine, render it a convenient agent for obtaining the two latter. In fact the preparation of free bromine and iodine depends mainly on the decomposition of their hydrides by chlorine. A further chemical attribute of chlorine is its tendency to form with most metals soluble compounds. This behavior is the more readily utilized, since hydrochloric acid, which may be regarded as an industrial by-product, affords a very cheap means of obtaining soluble chlorides af almost all the metals. Free chlorine is also employed as a solvent, *e. g.*, for separating and refining the precious metals, with the exception of silver.

Bromine and iodine are valuable to the chemist not so much on account of their energetic affinities as by the feeble power with which they maintain their position when combined with electro-positive elements. This weaker affinity plays a part, as already mentioned, in their production, and is at the same time the foundation of their uses. Photography, in particular, is based upon the instability of

the bromide, iodide (and chloride) of silver; scientific chemistry and tinctorial chemistry utilize it extensively on account of the readiness with which bromides and iodides of the hydrocarbons and of the metals are mutually decomposed.

Of less importance to the chemist is the property of bromine and iodine—like many of the rarer elements—of excercising a perturbing action upon the healthy animal organism. The physician employs them, therefore, chiefly in combination with the alkaline metals, as valuable remedies.

Fluorine holds a distinct position from the remaining halogens, both in scientific chemistry and in technology. It is endowed with such powerful affinities as to be scarcely known in the free state, whence its energies, as a general rule, do not admit of application. Its affinity for silicium is alone utilized, hydrofluoric acid being employed for the decomposition of silicates, etching on glass, &c.

Chlorine and its Compounds.

Hydrochloric Acid.—As the initial point for the entire production of free chlorine and its compounds we still employ hydrochloric acid, which is obtained in the largest quantity as a by-product in the manufacture of alkali on Leblanc's process. The amount of hydrochloric acid liberated in this process is so enormous that if it were entirely converted into the transportable liquid acid the supply would far exceed the consumption, greatly as this has been recently extended. Hence, especially in England, little pains had been taken for the perfect condensation of the acid gas, so that vast quantities escaped into the air, and, becoming dissolved in atmospheric water, returned as rain in the neighborhood of the works and effected manifold damage, giving thus rise to well-founded complaints on the part of the owners of the adjacent land. This rendered in England a law necessary known as the "Alkali Act" prohibiting the escape of more than 5 per cent of the total hydrochloric acid evolved. In consequence the soda manufacturers were compelled to pay increased attention to the condensation of the hydrochloric acid. The arrangements for this purpose have been improved, not only in England, but the question has been zealously taken up in France and Germany. The inducement was, on the one hand, the growing consumption of the acid and its consequent increasing value, and on the other, a wish to anticipate the complaints of the neighboring residents and thus escape a law similar to that of England, the operation of which occasions the

manufacturers decided inconvenience. In future it will be still more necessary to condense the hydrochloric acid due to Leblanc's process, as far as possible, if, as is probable, the manufacture of soda on the "ammonia" process should become more general.

Whilst formerly it was deemed sufficient to make use of the well known *bombonnes* (groups of Woolf's bottles on a large scale) in which the gases escaping from the pan were absorbed, the method of coke-towers has become latterly universal, which enables the diluted gases to be arrested as they escape from the calcining furnace. This is greatly facilitated by the increasing use of muffle-furnaces instead of reverberatories.

The conditions to be observed in order to obtain the most perfect possible condensation of the hydrochloric acid gas, as ascertained by the exhaustive researches of E. Kopp,* G. Lunge,† and A. Smith, are as follows:—

A sufficient cooling of the gases before entering the absorbing apparatus, a sufficient volume of water, the largest possible surface of contact between the water and the gas, and the simplest possible construction of the apparatus for condensation.

The refrigeration of the gases, especially those from the calcination spaces, is most conveniently effected by means of cold air. Cold water is, indeed, employed as a refrigerant in some establishments in Germany and France, but the difficulties involved can only be successfully combatted on the small scale. In larger works cold air is preferable and is universally employed in England. Refrigeration becomes absolutely necessary where reverberatories are used for calcination, and the gases pass at once into the coke-towers. In this case the heat is so considerable that the coke may take fire, a result which has actually happened.

The apparatus employed in English works for cooling the gases consists chiefly of pipes which are either conducted straight onwards with a slight inclination, or where it is desirable to economize space, are arranged descending and ascending in the form of a U. These pipes are made of fire-clay of from 0·4 to 0·6 metre internal diameter, and fit into each other by means of contracted ends. The joints are made good with a mixture of fire-clay and coal-tar. If possible this series of pipes is carried with a fall of 0·05 to 1 metre for 35 to 70

* E. Kopp, *Moniteur scientifique*, 1866, p. 611.

† G. Lunge, *Dingl. Pol. Journ.*, clxxxviii, 322.

metres to the condensers, which, to obtain the strongest possible acid, may be either Woolf's bottles or, as in many cases preferable, stone troughs. The latter have the great advantage that the many elbows of the connecting pipes, which impede the movement of the gases, may be more easily dispensed with. They are best made of sand-stone slabs let into each other and held together with tie rods which pass through the projecting ends of the side slabs. Or the slabs are fitted together with their edges beveled to an angle of 45°, tightened by the interposition of strips of caoutchouc, and the whole clamped together with a somewhat expensive iron frame work. Lunge decidedly recommends the former plan. Troughs cut out of a solid block are sometimes used in Germany, especially in the neighborhood of sand-stone quarries. Such, however, if of large size are very costly, and if once damaged can scarcely be repaired. The sand-stone used in Germany after it has been shaped out requires to be saturated with coal-tar, as it is otherwise unable to resist the action of the acid. Very hard stone, such as the carbonaceous sandstone (Kohlen sandstein) quarried at Herdecke and Wetter, in Westphalia (Hasenclever), does not require this preparation. Many English sandstones are sufficiently compact to resist the muriatic acid without any preparation (see the section on bromine below).

In these stone troughs a great part of the muriatic acid is condensed. The gases not condensed pass into the base of a coke-tower divided into two sections. They ascend in one of these and descend in a pipe fixed outside the tower, ascend again in the second compartment of the tower, and are thence led through a descending pipe into the chimney. The exit pipe is fitted with a damper to regulate the draught. The second compartment of the tower serves especially to free the gases which pass through it entirely from muriatic acid. According to the arrangement described the gas traverses both sections of the tower in a direction opposite to the descending current of water. It would be possible to dispense with the two external descending earthenware pipes if the two towers were connected above, and the gas were allowed to pass in the second tower in the same direction as the water. Thereby, however, a much less perfect condensation would ensue in the second tower, and a larger descending flow of water would be required.

Where two muffle furnaces are in use with a total weekly yield of 8000 kilos. of salt cake on the system of condensation just mentioned,

15 metres in height and 2·3 metres in the square (interior measurement) suffice for the production of a strong acid. At any rate the condensation is so perfect, that in the second, or "washing tower," which may measure something less in the clear, the acid obtained does not exceed the strength of 1° B., which may be let pass away in each channel, if it is not preferred to let it pass down in the second or condensation tower. The acid from the first tower may be further strengthened in the first trough—in which most of the accompanying sulphuric acid is condensed—with a view to its utilization in the manfacture of chloride of lime.

Particular attention must be paid to the towers when fitted up. They are filled either with bricks or coke, the latter material being preferable on account of its larger surface, greater power of resisting hydrochloric acid, and its less weight. Sometimes a combination of both materials is made, the bricks being placed below and the coke above. In order to distribute the water equally among the contents of the tower we employ either a rocking trough or Segner's water-wheel. The coke must be filled in neither too compact nor too loosely; the former error impeding the movement of the gases, and the latter leading to the subsequent settlement of particular portions. In both these cases the gas selects the more open passages, and a large part of the tower may be thrown out of action. The towers may also deviate from the perpendicular, when the water runs down one side alone, leaving the other nearly dry, and as these parts allow the freest passage to the gases the actual absorbtion becomes very small.

A very convenient arrangement for condensation is the combination of coke towers and Woolff's bottles, introduced at Stolberg and elsewere. The gases escaping from the salt cake pans and muffle furnaces, considerably cooled in passing through a long series of earthenware pipes, are led into a long row of Woolff's tubulated on both sides at a fourth of their height, reckoning from the bottom and connected by caoutchouc tubes well secured with cement; thus the liquid in all stands at the same level. From these the gases enter the coke towers, whence the condensed acid flows back into the Woolff's bottles to be there strengthened by the muriatic acid gas continually streaming over it, and thus reaches the required strength (Hasenclever).

In England the condensation of the hydrochloric acid is carried so far that whilst in the first year of the operation of the Alkali Act,